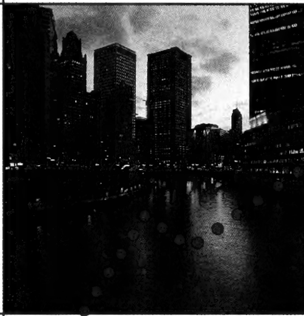
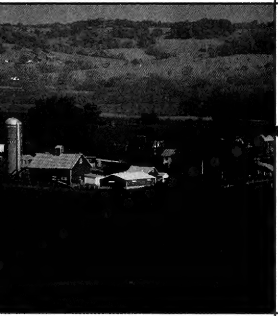
The Changing Illinois Environment: Critical Trends





Technical Report of the Critical Trends Assessment Project
Volume 6: Sources of Environmental Stress

Illinois Department of
Energy and Natural Resources

June 1994 ILENR/RE-EA-94/05(6)

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Volume 6: Sources of Environmental Stress

Illinois Department of Energy and Natural Resources
Office of Research and Planning
325 West Adams Street, Room 300
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Volume 1: Air Resources

Volume 2: Water Resources

Volume 3: Ecological Resources

Volume 4: Earth Resources

Volume 5: Waste Generation and Management

Volume 6: Sources of Environmental Stress

Volume 7: Bibliography

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ABOUT THE CRITICAL TRENDS ASSESSMENT PROJECT

The Critical Trends Assessment Project (CTAP) is an on-going process established to describe changes in ecological conditions in Illinois. The initial two-year effort involved staff of the Illinois Department of Energy and Natural Resources (ENR), including the Office of Research and Planning, the Geological, Natural History and Water surveys and the Hazardous Waste Research and Information Center. They worked with the assistance of the Illinois Environmental Protection Agency and the Illinois departments of Agriculture, Conservation, Mines and Minerals, Nuclear Safety, Public Health, and Transportation (Division of Water Resources), among other agencies.

CTAP investigators adopted a "source-receptor" model as the basis for analysis. Sources were defined as human activities that affect environmental and ecological conditions and were split into categories as follows: manufacturing, transportation, urban dynamics, resource extraction, electricity generation and transmission, and waste systems. Receptors included forests, agro-ecosystems, streams and rivers, lakes, prairies and savannas, wetlands, and human populations.

The results are contained in a seven-volume technical report, *The Changing Illinois Environment: Critical Trends*, consisting of *Volume 1: Air Resources, Volume 2: Water Resources, Volume 3: Ecological Resources, Volume 4: Earth Resources, Volume 5: Waste Generation and Management, Volume 6: Sources of Environmental Stress*, and *Volume 7: Bibliography.* Volumes 1-6 are synopsized in a summary report.

The next step in the CTAP process is to develop, test, and implement tools to systematically monitor changes in ecological and environmental conditions in Illinois. Given real-world constraints on budgets and human resources, this has to be done in a practical and cost-effective way, using new technologies for monitoring, data collection and assessments.

As part of this effort, CTAP participants have begun to use advanced geographic information systems (GIS) and satellite imagery to map changes in Illinois' ecosystems and to develop ecological indicators (similar in concept to economic indicators) that can be evaluated for their use in long-term monitoring. The intent is to recruit, train, and organize networks of people — high school science classes, citizen volunteer groups — to supplement scientific data collection to help gauge trends in ecological conditions.

Many of the databases developed during the project are available to the public as either spreadsheet files or ARC-INFO files. Individuals who wish to obtain additional information or participate in CTAP programs may call 217/785-0138, TDD customers may call 217/785-0211, or persons may write:

Critical Trends Assessment Project
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Copies of the summary report and volumes 1-7 of the technical report are available from the ENR Clearinghouse at 1/800/252-8955. TDD customers call 1/800/526-0844, the Illinois Relay Center. CTAP information and forum discussions can also be accessed electronically at 1/800/528-5486.

FOREWORD

"If we could first know where we are
and whither we are tending,
we could better judge what we do
and how to do it..."
Abraham Lincoln

Imagine that we knew nothing about the size, direction, and composition of our economy. We would each know a little, i.e., what was happening to us directly, but none of us would know much about the broader trends in the economy — the level or rate of housing starts, interest rates, retail sales, trade deficits, or unemployment rates. We might react to things that happened to us directly, or react to events that we had heard about — events that may or may not have actually occurred.

Fortunately, the information base on economic trends is extensive, is updated regularly, and is easily accessible. Designed to describe the condition of the economy and how it is changing, the information base provides the foundation for both economic policy and personal finance decisions. Typical economic decisions are all framed by empirical knowledge about what is happening in the general economy. Without it, we would have no rational way of timing these decisions and no way of judging whether they were correct relative to trends in the general economy.

Unfortunately, this is not the case with regard to changes in environmental conditions. Environmental data has generally been collected for regulatory and management purposes, using information systems designed to answer very site-, pollutant-, or species-specific questions. This effort has been essential in achieving the many pollution control successes of the last generation. However, it does not provide a systematic, empirical database similar to the economic database which describes trends in the general environment and provides a foundation for both environmental policy and, perhaps more importantly, personal decisions. The Critical Trends Assessment Project (CTAP) is designed to begin developing such a database.

As a first step, CTAP investigators inventoried existing data to determine what is known and not known about historical ecological conditions and to identify meaningful trends. Three general conclusions can be drawn from CTAP's initial investigations:

Conclusion No. 1: The emission and discharge of regulated pollutants over the past 20 years has declined, in some cases dramatically. Among the findings:

- Between 1973 and 1989, air emissions of particulate matter from manufacturing have dropped 87%, those of sulfur oxides 67%, nitrogen oxides 69%, hydrocarbons 45%, and carbon monoxide 59%.
- Emissions from cars and light trucks of both carbon monoxide and volatile organic compounds were down 47% in 1991 from 1973 levels.
- Lead concentrations were down substantially in all areas of the state over the 1978-1990 period, reflecting the phase-out of leaded gasoline.
- From 1987 to 1992, major municipal sewage treatment facilities showed reductions in loading of biological/carbonaceous oxygen demand, ammonia, total suspended solids and chlorine residuals that ranged from 25 to 72%.
- Emissions into streams of chromium, copper, cyanide, and phenols from major non-municipal manufacturing and utility facilities (most of them industrial) also showed declines over the years 1987-1992 ranging from 37% to 53%.

Conclusion No. 2: Existing data suggest that the condition of natural ecosystems in Illinois is rapidly declining as a result of fragmentation and continual stress. Among the findings:

- Forest fragmentation has reduced the ability of Illinois forests to maintain biological integrity. In one Illinois forest, neotropical migrant birds that once accounted for more than 75% of breeding birds now make up less than half those numbers.

- In the past century, one in seven native fish species in Lake Michigan was either extirpated or suffered severe population crashes and exotics have assumed the roles of major predators and major forage species.

- Four of five of the state's prairie remnants are smaller than ten acres and one in three is smaller than one acre — too small to function as self-sustaining ecosystems.

- Long-term records of mussel populations for four rivers in east central Illinois reveal large reductions in numbers of all species over the last 40 years, apparently as suitable habitat was lost to siltation and other changes.

- Exotic species invasions of Illinois forests are increasing in severity and scope.

Conclusion No. 3: Data designed to monitor compliance with environmental regulations or the status of individual species are not sufficient to assess ecosystem health statewide. Among the findings:

- Researchers must describe the spatial contours of air pollutant concentrations statewide using a limited number of sampling sites concentrated in Chicago and the East St. Louis metro area.

- Much more research is needed on the ecology of large rivers, in particular the effects of human manipulation.

- The length of Illinois' longest stream gaging records is generally not sufficient to identify fluctuations that recur less frequently than every few decades.

- The Sediment Benchmark Network was set up in 1981 with some 120 instream sediment data stations; by 1990 the network had shrunk to 40 stations, the majority of which have data for only one to three years.

CTAP is designed to begin to help address the complex problems Illinois faces in making environmental policy on a sound ecosystem basis. The next edition of the Critical Trends Assessment Project, two years hence, should have more answers about trends in Illinois' environmental and ecological conditions to help determine an effective and economical environmental policy for Illinois.

Nat. Hist. Surv.

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VOLUME SUMMARY

The sources of environmental stress (pollution and changing land use) examined in the Critical Trends Assessment Project are manufacturing, agriculture, transportation, urban dynamics, resource extraction, electricity generation, and waste systems. *Volume 6* discusses manufacturing, transportation, urban dynamics, and electricity generation, in addition to greenhouse gases, indoor radon exposure, accidental releases, and wastewater discharge. Also included is an analysis of human exposure to air and water pollutants.

The remaining categories of stress — agriculture, resource extraction and waste systems — are covered in *Volume 3: Ecological Resources*, *Volume 5: Earth Resources*, and *Volume 4: Waste Generation and Management*. *Volume 4* also contains a discussion of Toxic Release Inventory data.

Manufacturing

In the manufacturing sector (SIC codes 20-39), a variety of pollutants are emitted into the atmosphere, several of which are regulated — particulates, sulfur oxides, nitrogen oxides, hydrocarbons, and carbon monoxide. Emissions data for 1973 through 1989 was available from the IEPA Total Air System data base. Over the sixteen-year period, statewide emissions of all of these pollutants have decreased, particularly emissions of sulfur dioxide and particulates. Emissions of particulates are down 87%; sulfur oxides, 67%; nitrogen oxides, 69%; hydrocarbons, 45%; and carbon monoxide, 59%.

While emissions have decreased, so have the number of manufacturing employees statewide, down from 1.42 million in 1968 to 1.04 million in 1989, a reduction of 27%. The value of manufacturing output, on the other hand, increased. In 1987 dollars, output rose from $117 billion to $127 billion, an increase of almost 9%.

Using manufacturing output and emissions figures, an index for 'tons of emissions per million dollars of output' was calculated for each pollutant to determine trends in pollution control efficiency (Table 1). Overall, particulates had the greatest reduction in emissions per million dollars of output, from 4.1 tons emitted per million to .52 tons per million.

Table 1. Tons of manufacturing emissions per million dollars of output.

Year	Particulates (tons of emissions /million $ of output)	SO2 (tons of emissions /million $ of output)	NOx (tons of emissions /million $ of output)	HC (tons of emissions /million $ of output)	CO (tons of emissions /million $ of output)
1973	4.10	5.50	1.94	2.43	1.88
1983	0.72	2.52	1.08	1.51	1.04
1989	0.52	1.90	0.77	1.06	0.80
Percentage Changes					
1973-1983	-82.38%	-54.28%	-44.00%	-37.79%	-44.51%
1983-1989	-27.70%	-24.62%	-28.80%	-30.11%	-23.51%
1973-1989	-87.31%	-65.54%	-60.13%	-56.53%	-57.55%

To estimate trends in wastewater discharge, the Illinois Environmental Protection Agency provided a data analysis from the Permit Compliance System. The analysis included only major facilities (both manufacturing and electric utilities) which reported an equivalent number of sample measurements for a specific parameter every year from 1987 through 1992. The pollutant discharge loading estimates for the four parameters analyzed — chromium, copper, cyanide, and phenols — decreased during the time period (Figure 1).

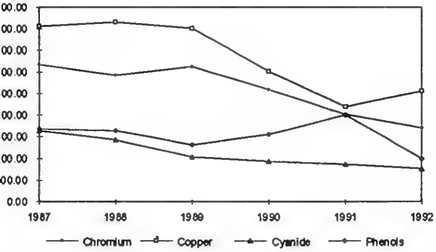

Figure 1. Wastewater loading estimates for major manufacturing facilities and electric utilities.

Transportation

In the transportation sector, air emissions from four major modes were examined — highway, rail, air, and water — all of which emit significant quantities of NOx, volatile organic compounds (VOCs) and CO. Highway vehicles account for about 80% of NOx emissions and for more than 95% of VOCs and CO from transportation sources. Water transportation emits the smallest amount of pollutants, followed by rail and air transportation.

Total transportation emissions dropped significantly between 1973 and 1991, with a 20% decrease in NOx and a 45% decrease in VOCs and CO (Figure 2). This occurred despite tremendous growth in most transportation activity. Highway miles traveled grew by more than 40% during this time period, while both the number of air passengers and recreational boating grew by 100%. (Only rail travel and marine freight showed moderate decreases in activity.) The drop in emissions can be accounted for by increasingly strict emission standards for cars and light trucks. In certain transportation modes, however, emissions have increased — NOx is up from trucks, VOCs are up from water traffic, and CO is up from both air and water travel. The growth in emissions in these cases reflects the rapid growth in truck traffic, recreational boating, and general aviation.

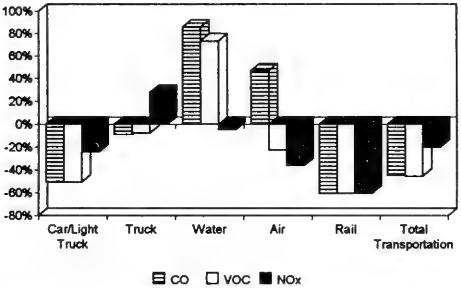

Figure 2. Percent change in transportation emissions from 1973-91, by mode.

On a geographic basis, emissions have uniformly decreased, with the major exception of the Chicago collar counties. While VOC and CO emissions around the state dropped by nearly half between 1973 and 1991, they only decreased by about one-third in the collar counties. NOx emissions actually increased slightly in the collar counties, compared to a more than 20% decrease in the rest of the state. This reflects the rapid economic growth that has occurred in suburban Chicago in the last twenty years.

Another trend is the increasing dependence on heavy trucks to move freight. During the last twenty years, vehicle miles traveled by heavy trucks have increased by nearly 100%. Deep draft shipments on the Great Lakes, on the other hand, have declined by 75% and rail activity (measured by fuel use) has dropped by 60%. Barge shipments have remained steady or increased only slightly.

The displacement of barges and rail by trucks has resulted in higher air emissions from freight transportation (Table 2). Trucks consume eight times as much energy per ton-mile of freight as barge or rail. Taking into account the respective emission factors for each transportation mode, trucks emit 3 to 70 times as much air pollutants per ton-mile as barges or rail. Barges are the most efficient, followed closely by rail. The discrepancy between truck and the other freight modes is not as great when taking into account the value of shipments. The value of truck freight from manufacturing establishments, for example, is approximately three times that of barge and rail freight.

Table 2. Efficiency of freight shipments by mode of transportation.

Freight Mode	Btu/ton-mile			$/ton-mile		
barge	403			$1.32		
rail	427			$1.41		
truck	3483			$3.99		
	NOx	VOC	CO	NOx	VOC	CO
	(lb/1000 ton-miles)			(lb/$1000)		
barge	0.81	0.15	0.29	0.61	0.11	0.22
rail	1.70	0.12	0.58	1.20	0.09	0.41
truck	5.14	3.08	21.42	1.29	0.77	5.37

Electricity Generation

In 1960, Illinois utilities produced more than 42 billion kWh of electricity, 90% of which were generated using coal, 9.1% using natural gas, and 0.04% using petroleum. In 1970, coal provided 77% of the statewide fuel mix, natural gas provided 16%, petroleum 3.5% and nuclear 3.4%. By 1990, total utility generation was 126.9 billion kWh. Of the total, 42.4% was generated from coal, 0.3% from fuel oil, 0.7% from gas and 56.6% from nuclear. Total generation grew 200% over the 30-year period, with most of the increase being accommodated by nuclear power.

Over the past twenty years, fossil fuel emissions have declined substantially. SO_2 declined 40%, NOx, 19%, particulates, 81%, and CO, 36% (Figure 3). On the other hand, even while the volume of low-level radioactive wastes has declined, the level of radioactivity from low-level waste has increased. Using a five-year average, the level of radioactivity in 1974 was 426 curies, in 1983 it was more than 10 thousand curies, and in 1991 it was 41 thousand curies. Subsequently, the ratio of megawatt-hours per curie of low level waste decreased from 9.39 thousand mWh in 1983 to 2.69 thousand mWh by 1989.

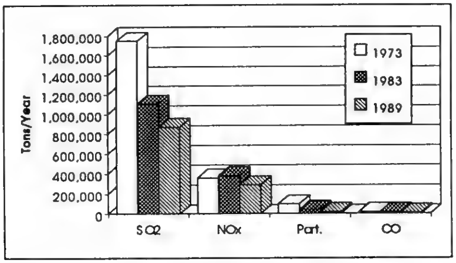

Figure 3. Electric utility emissions, 1973-1989.

Urban Dynamics

The CTAP source category 'urban dynamics' includes urban and built-up lands and the populace which lives and works there, and the urban economic system — the flow of money, goods and services, and materials. For this study, the urban economic sector includes construction, wholesale trade, retail trade, finance, insurance, real estate, services, and government.

The overall economic trends in these sectors during the 1970's and 1980's are generally upward, with the services sector growing the most, with output up 87% over 20 years and employment more than doubled.

Statewide population has grown only slightly since 1970, although it has shifted slightly in geographic location. A little over 15% of the population live in rural areas, and as many people live on the fringes of large cities as live in the cities, about 37% (Figure 4).

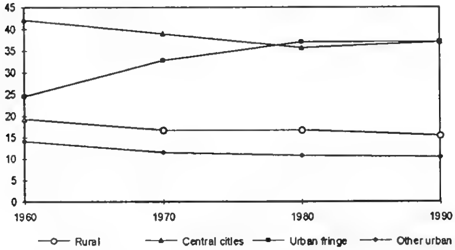

Figure 4. Population distribution (percentage of total) in urban areas, 1960-1990.

Most economic and population growth is taking place in the collar counties around Chicago, spurring slight increases in emissions of ozone precursors — volatile organic compounds, nitrogen dioxide and carbon monoxide — in these areas. Land is rapidly being developed in these growth areas, decreasing urban density but increasing the stress on surrounding ecosystems and agricultural lands. The trend to lower urban density is particularly evident in the residential sector, as larger houses are being built for fewer people per household. Over 30 years, the median number of rooms per housing unit has increased from 4.8 to 5.4, while the number of persons per unit has declined from 2.9 to 2.3.

Although point emissions of criteria air pollutants from urban sources are small compared to other sectors, such as manufacturing and utilities, some are large enough to require a permit and be included in IEPA's Total Air System (TAS) database. Figure 5 shows statewide trends in these urban sector point source emissions (taken from the TAS) of five criteria air pollutants. Overall, only carbon monoxide increases slightly in each three-year period, with the most significant change occurring in the service sector. From 1983 to 1989 service sector CO emissions grew from 21% to 33% of the total.

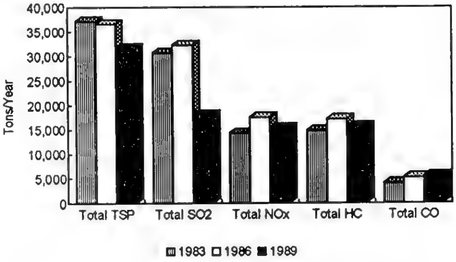

Figure 5. Statewide urban point source emissions, 1983, 1986 and 1989.

To estimate trends in municipal wastewater discharge, the Illinois Environmental Protection Agency provided a data analysis from the Permit Compliance System. The analysis only included those major facilities which reported an equivalent number of sample measurements for a specific parameter every year from 1987 through 1992. The pollutant discharge loading estimates for the parameters analyzed — biological/carbonaceous biological oxygen demand (BOD/CBOD), total suspended solids (TSS), and ammonia and chlorine residual — decreased during this time period (Figure 6).

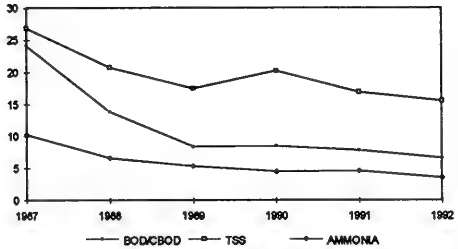

Figure 6. Wastewater loading estimates for major municipalities.

Indoor Radon Exposure

Various studies have shown that elevated levels of indoor radon occur in Illinois homes, with estimates varying from 19% to 31% of measurements exceeding the USEPA guideline of 4 pCi/L. According to a 1992 study in which the state was assessed for geologic radon potential, most of Illinois has high or moderate potential for elevated radon, with extreme southern Illinois having the lowest potential. This finding was supported by a map of median radon measurements plotted by zipcode throughout the state. The map illustrated that any area in Illinois could have indoor radon screening measurements above 4 pCi/L, while only a few areas had results greater than 10 pCi/L.

Greenhouse Gases

Three of the major greenhouse gases emitted in Illinois are carbon dioxide, methane, and nitrous oxide, with carbon dioxide from fossil fuel combustion contributing the bulk of emissions. Emissions data for 1970, 1980, and 1990, obtained from the *Illinois Inventory of Greenhouse Gas Emissions,* shows that statewide emissions have declined during the last twenty years (Figure 7), particularly emissions from fossil fuel combustion. The decrease can be attributed to several factors. 1. Illinois has moved from coal-intensive to nuclear-intensive production of electricity. 2. Industrial, commercial, and residential use of oil and coal has declined, while use of natural gas, which has a lower emission factor, has increased. 3. Energy efficiency improvements have reduced energy use. 4. In spite of increases in population and waste generation, landfills are emitting less methane because more materials are being recycled and yard wastes are no longer landfilled. As larger landfills install gas recovery systems, methane emissions are expected to decrease further.

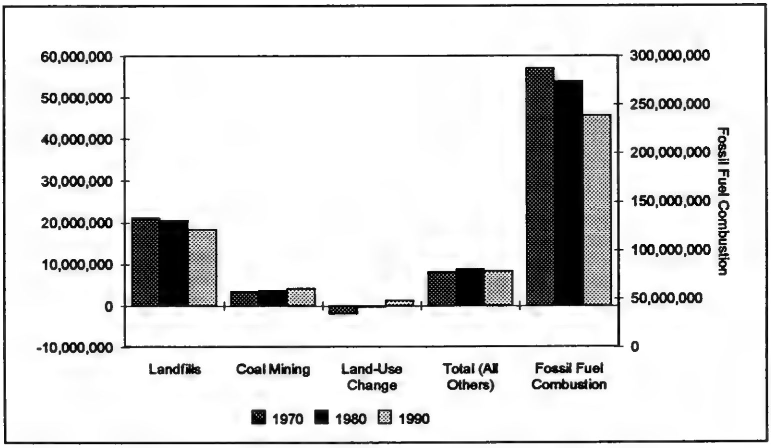

Figure 7. Illinois greenhouse gas emissions in CO_2 equivalents, 1970 - 1990.

Accidental Releases

Accidental releases of chemical products and wastes have been recorded in an IEPA Incident Database since the early 1970's. Although the number of incidents reported has steadily increased over the years, a significant portion of the increase can be attributed to changes in reporting requirements. Fuels are the most commonly reported materials involved in accidental releases, with anhydrous ammonia, polychlorinated biphenyls, sulfuric acid and chlorine also frequently reported. Although most incidents have occurred in the populated counties around Chicago or St. Louis, significant spills have occurred throughout the state, in rural as well as urban counties.

Human Exposure to Air Pollutants

To assess human exposure to air pollutants, ambient measurements for criteria air pollutants — sulfur dioxide (SO_2), ozone (O_3), lead (Pb), carbon monoxide (CO), nitric oxides (NOx) and total suspended particulates (TSP) — were compared to their legal standards. Those above the standard were assumed to present some risk and those below the standard were assumed to present no risk. Using data from the Illinois Environmental Protection Agency's annual reports on air quality, 1978 through 1990, a Geographic Information System was used to place a one-mile buffer around air quality stations which had at least one measurement recorded above the legal standard.

Given the assumptions made in the analysis, exposure to the six pollutants has declined considerably. The NO_2 standard has not been exceeded since 1980, the lead standard since 1982, and the SO_2 standard since 1988. CO has been exceeded only once since 1985. Although TSP and ozone had exceedances every year during the time period, exposure levels declined significantly, particularly for TSP.

Human Exposure to Water Pollutants

The IEPA public water supply Restricted Status List was used as a surrogate for drinking water quality information. Only those facilities restricted because of drinking water violations were included in the analysis. Trends were developed for facilities restricted because of the following parameters: radium, fluoride, nitrates, and 'other' — total trihalomethanes, organics, barium and miscellaneous compounds (Figure 8). While radium and fluoride are naturally-occurring substances in Illinois groundwater, nitrates typically occur in drinking water as the result of fertilizer application, feed-lot runoff, or leaking septic tanks. Trihalomethanes are largely the result of chlorination, part of the water treatment process.

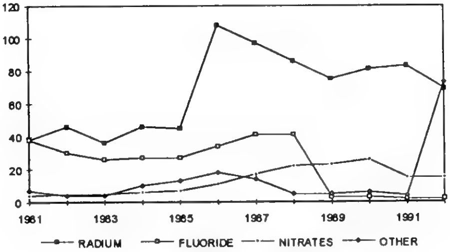

Figure 8. PWS facilities on restricted status.

During 1986, eleven percent of all public water supply systems were on restricted status due to contaminants, the highest percentage of the twelve-year period. The number of facilities restricted for radium increased 64% between 1981 and 1986, then declined considerably. This most likely was due to facilities switching to wells in shallow aquifers or to Lake Michigan as their source of supply. The number of facilities restricted due to fluoride decreased significantly after 1988, from 41 facilities to two by 1992. Facilities listed for nitrates increased 84% between 1981 and 1990, but the numbers have since declined, from 26 facilities in 1990 to 15 facilities in 1992.

The 'other' category owes its dramatic increase in 1992 to a significant number of facilities being listed for total trihalomethanes (TTHM), a disinfection by-product. It is assumed that this increase was due to a 1991 change in the TTHM regulations which expanded the universe of facilities subject to the TTHM standard.

Summary

Overall, economic output for the sectors studied generally increased between 1970 and 1990. Transportation activity and electricity generation also increased. Over the same time period, however, emissions of traditionally regulated pollutants decreased in both air and water. Accompanying the decrease in water and air emissions of these pollutants is a decrease in human exposure to them.

MANUFACTURING

The CTAP source category 'manufacturing' includes Standard Industrial Classification (SIC) Codes 20-39[1] -- establishments that chemically or mechanically transform materials or substances, which have been produced outside the manufacturing category, into new products. Manufacturers obtain these semi-finished products from SIC categories which are generally involved with natural resources such as agriculture, forestry, fishing, mining and quarrying (OMB 1987). Table 1 lists two digit manufacturing SIC codes.

Table 1: Manufacturing Sector
Standard Industrial Classification Code

Short Title	Code
Food and Kindred Products	20
Tobacco Manufacturers	21
Textile Mill Products	22
Apparel and Other Textile	23
Lumber and Wood Products	24
Furniture and Fixtures	25
Paper and Allied Products	26
Printing and Publishing	27
Chemicals and Allied Products	28
Petroleum and Coal Products	29
Rubber and Miscellaneous Plastics	30
Leather and Leather Products	31
Stone, Clay and Glass Products	32
Primary Metal Industries	33
Fabricated Metal Products	34
Machinery, Except Electrical	35
Electric and Electronic Equipment	36
Transportation Equipment	37
Instruments and Related Products	38
Miscellaneous Manufacturing	39

Source: Standard Industrial Classification Manual, Office of Management and Budget, 1987.

ECONOMIC TRENDS

During the twenty-one year period from 1968 to 1989, the number of manufacturing facilities in Illinois decreased slightly. The biggest decline was in food products, which dropped 40%. However, the number of firms in three other categories increased -- SIC 34, fabricated metal products, grew 6%; SIC 35, machinery, grew 11%; and SIC 27, printing, grew 28%.

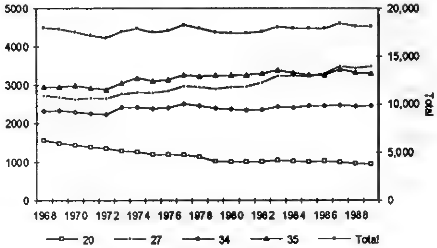

Figure 1. Number of manufacturing firms, select SICs and total.

Although the number of manufacturing firms has changed only slightly, the number of manufacturing employees has changed significantly. Statewide, the number of individuals employed by the manufacturing sector in 1989 was 27% less than the number employed in 1968, from 1.42 million to 1.04 million (Figure 2). Employment in the three largest SICs in 1968, SIC 34 (fabricated metal products), 35 (machinery), and 36 (electric and electronic equipment), declined 25, 33 and 46 percent respectively.

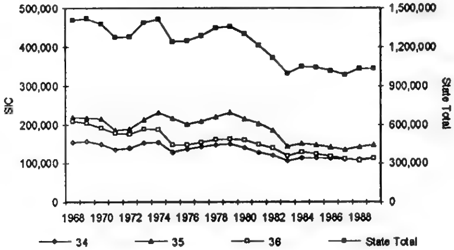

Figure 2. Number of manufacturing employees, select SICs and total.

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[1] "The Standard Industrial Classification (SIC) is the statistical classification standard underlying all establishment-based Federal economic statistics classified by industry."(OMB 1987, p3). "The SIC was developed for use in the classification of establishments by type of activity in which they are engaged; for purposes of facilitating the collection, tabulation, presentation and analysis of data relating to establishments; and for promoting uniformity and comparability in the presentation of statistical data collected by various agencies of the United States Government, State agencies, trade associations, and private research organizations." (OMB 1987, p11). The SIC code is thus used by the Federal government to promote comparability when describing the U.S. economy. The CTAP adopted the use of the SIC Code in order to classify sources of stress on the environment consistent within this economic framework.

Even though employment has declined considerably, the value of manufacturing output (in 1987 dollars) has increased almost 9%, from $117 billion to $127 billion. Value of output was calculated using factors derived from the Regional Economic Model, which express the value of output per employee within each SIC Code for each year. These factors were then multiplied by the number of employees in each year within each SIC Code to obtain the statewide value of manufacturing output. The number of employees was found in the Illinois County Business Patterns for each applicable year.

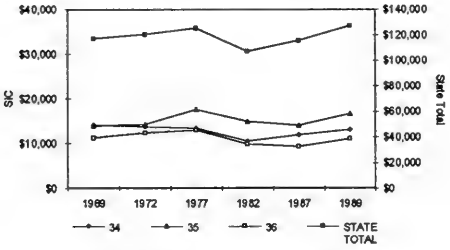

Figure 3. Manufacturing output (millions).

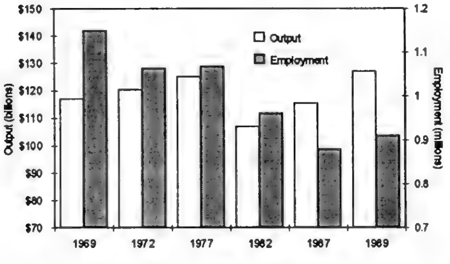

Figure 4. Statewide output and employment.

Within several counties and metropolitan statistical areas (MSA's)[2], striking changes took place over the twenty years. Cook County and the Davenport/Rock Island/Moline and St. Louis MSA's experienced significant losses, with output in Cook County and the St. Louis MSA declining by 15% and in the Davenport/Rock Island/Moline MSA by 9%. In the collar counties, output increased, with DuPage County leading at 431%, followed by McHenry County at 183% and Lake County at 135%. In the university MSA's of Champaign/Urbana/Rantoul and Bloomington/Normal MSA, both employment and output increased, with output up 358% and 171%, respectively. The following section discusses economic trends in counties and MSA's where major changes have occurred.

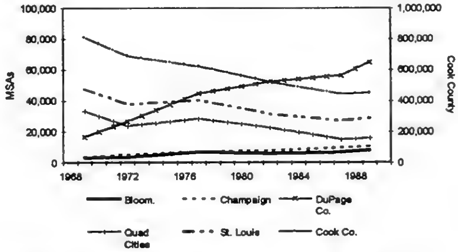

Figure 5. Number of manufacturing employees for select areas.

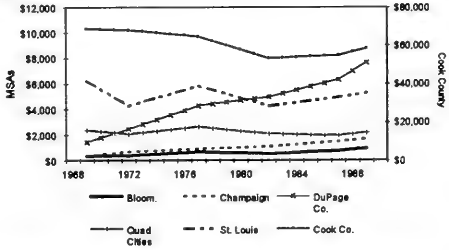

Figure 6. Manufacturing output (millions) for select areas.

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[2] Metropolitan areas (MA's) within the State are "designated and defined by the Federal Office of Management and Budget (OMB), following a set of official published standards, with the aim of producing definitions that are as consistent as possible for all MA's nationwide. Metropolitan Statistical Areas (MSA's) are relatively free-standing MA's and are not closely associated with other MA's. These areas are typically surrounded by non metropolitan counties." (1990 Census of Population and Housing, Illinois, pp. A-8 and A-9).

DuPage County

The greatest amount of growth occurred in DuPage County, where output rose from $1.4 billion to $7.6 billion, an increase of 431%. Output in the paper industry increased more than twenty-fold, 2,023%. Twelve other industries more than doubled output and two new industries, textiles and apparel, began operating in the county. In addition to having the largest hike in output, DuPage County had the greatest increase in employment, from less than 17,000 to nearly 65,000 people, an increase of 289%. Employment increased in each manufacturing category, jumping most in the printing, paper, machinery/computers, and electrical equipment industries.

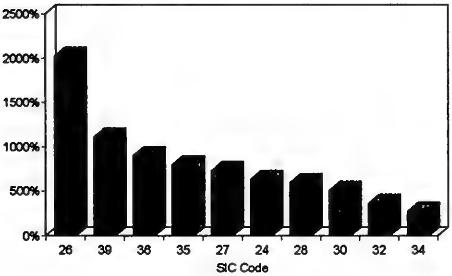

Figure 7. Percent change in DuPage County manufacturing output by SIC code, 1969-1989.

Champaign/Urbana/Rantoul MSA

Output in this MSA grew 358% during the time period investigated, rising from $0.4 billion to $1.7 billion. Four manufacturing industries grew more than 100%, with the food industry leading the way at 342% (a new Kraft production facility opened during this time frame), the apparel industry at 269%, machinery/computers at 244%, and electrical equipment at 126%. Seven new industries began operating in the area, while one, the furniture industry, ceased production.

MSA employment increased 183%, with food processing up 213%. Other large increases occurred in the printing, machinery/computers, and apparel industries. In addition to lost jobs in the furniture industry, the area lost 54% of the jobs previously available in the primary metals industry.

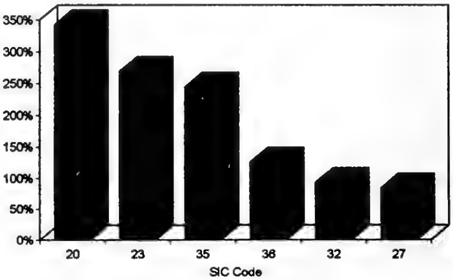

Figure 8. Percent change in Champaign manufacturing output by SIC code, 1969-1989.

Bloomington/Normal MSA

Manufacturing output increased 171% in the Bloomington/Normal MSA from 1969 to 1989. This was driven by the tremendous increase in the electrical equipment industry (SIC 36), which increased its output by nearly 1300%, from $26 million to over $368 million. Another large increase was noticed in the rubber industry (30) with growth of nearly 630%. Two industries suffered losses, food (20) and fabricated metals (34) saw output of their products decline by 36% and 50%, respectively.

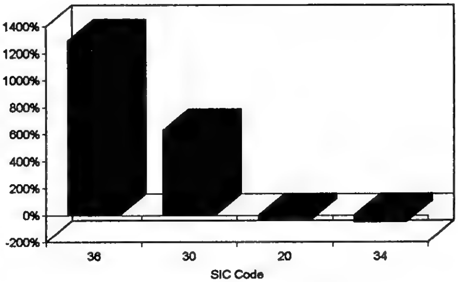

Figure 9. Percent change in Bloomington manufacturing output by SIC Code, 1969-1989.

This MSA experienced a 144% increase in manufacturing employment. The greatest growth occurred in the electrical equipment category, up 681% with rubber second at 400%. One new industry, transportation equipment, began operation. Countering with major losses in employment were the food and fabricated metals industries, down 55% and 61%, respectively.

Davenport/Rock Island/Moline MSA

Manufacturing output decreased nearly 9% during the 1969 to 1989 period ($2.4 billion to $2.2 billion). Decline hit ten industries, with instruments declining the most, by more than 79%, followed by the furniture industry, down 64%, and electrical equipment down 57%. However, five industries more than doubled the value of their output. The largest increase came in the chemical industry, with an increase of nearly 340%. Next was paper, with a 216% increase. Output in the food, apparel, and rubber industries grew by 156%, 154%, and 130%, respectively.

This area experienced the largest drop, 52%, in manufacturing employment. Nearly 87% of this loss is attributable to decreases in the machinery/computers industry, despite increases in the food (81%), paper (118%), and chemicals (162%) industries.

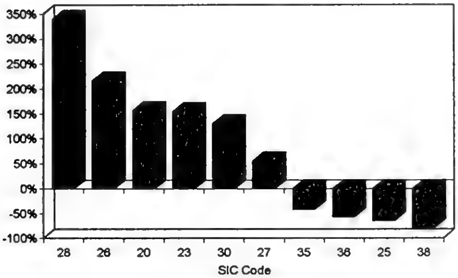

Figure 10. Percent change in Davenport/Rock Island/ Moline manufacturing output by SIC code, 1969-1989.

Cook County

Over the twenty-year period, overall manufacturing output declined more than 15%, from $68 billion in 1969 to $58 billion in 1989. Fifteen industries reduced output, with the greatest reductions occurring in tobacco, down 91%, and leather, down 62%. However, a few industries increased output, with textiles up 142% and rubber products up 55%.

In conjunction with the 15% drop in output was a 44% drop in employment. The number of workers declined from 809,000 to 450,000. Only one manufacturing industry, rubber, increased employment, up 6%, from 23,602 to 25,100 workers. The remaining nineteen industries cut their workforces. For example, in 1969 the leading employer was the electrical equipment industry with 151,692 workers. By 1989 the industry had only 60,370 employees, making it the third largest employer. The next largest drop in employment occurred in the machinery/ computers industry which fell from 97,000 to 48,000 workers.

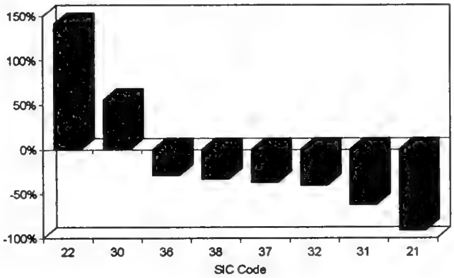

Figure 11. Percent change in Cook County manufacturing output by SIC code, 1969-1989.

St. Louis MSA

Similar to Cook County, output in the St. Louis MSA also declined 15%, from $6.2 billion in 1969 to $5.3 billion in 1989. Seven industries reduced output, with the largest decreases occurring in food, down 67%, and stone/clay, down 81%. Nine industries increased output, however, with the rubber industry growing more than 400%, fabricated metals 174% and machinery/computers 103%. One new industry was introduced -- instruments.

With the drop in output came a 39% drop in employment. Although the rubber industry increased employment 248% and fabricated metals 116%, these gains were more than offset by plummeting opportunities in the stone/clay, food, petroleum production, and primary metals industries, which experienced drops of 85%, 77%, 52%, and 49%, respectively.

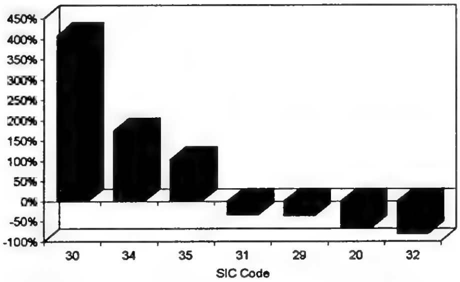

Figure 12. Percent change in St. Louis manufacturing output by SIC code, 1969-1989.

ENVIRONMENTAL TRENDS

Air Emissions

Manufacturing emits a variety of pollutants into the atmosphere, several of which are regulated -- particulates, sulfur oxides, nitrogen oxides, hydrocarbons, and carbon monoxide. Trends in their emissions were developed using IEPA's Total Air System data base. Over the sixteen-year period for which data was available, statewide emissions of all of these pollutants have decreased, particularly emissions of sulfur oxides and particulates. (Figure 13)

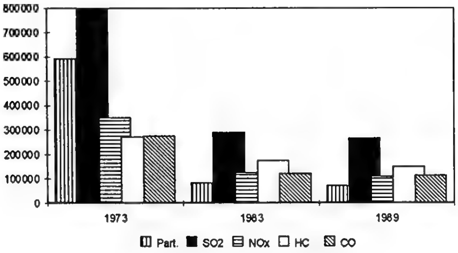

Figure 13. Statewide manufacturing emissions (tons).

Particulate emissions have been cut 87% since 1973, with the largest cuts (85%) occurring between 1973 and 1983. The major reductions occurred in Cook County (93%), Joliet (85%), Kankakee (97%), and Peoria (96%) MSA's. Figure 14 shows realized changes in Cook County, the collar counties, other MSA's, and non-MSA's (the remainder of the State). The collar counties are defined as the Aurora MSA (Kane and Kendall counties), the Joliet MSA (Will and Grundy counties), and DuPage, Lake, and McHenry counties.

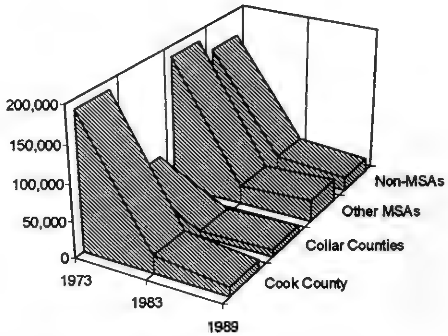

Figure 14. Particulate emissions (tons).

Sulfur oxide emissions decreased 67% between 1973 and 1989. Only the Champaign and Decatur MSA's experienced any substantial increase in SO2 emissions during these years. Cook County and the Peoria and Joliet MSA's, the three largest emitting areas in 1973, provided 79% of the statewide reductions.

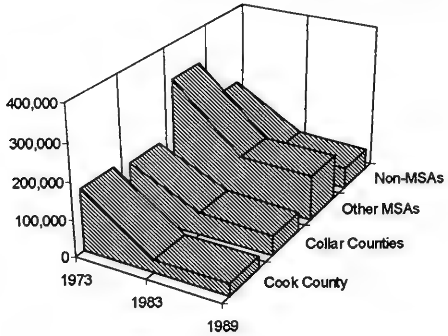

Figure 15. Sulfur oxides emissions (tons).

By 1989, statewide **nitrogen oxide** emissions were at 69% of their 1973 levels. Only the Decatur MSA and DuPage and McHenry counties saw an increase in NOx emissions, due primarily to growing manufacturing activity. All other areas in the state saw decreases of at least 50%, except for the St. Louis MSA, which had reductions of only 24%.

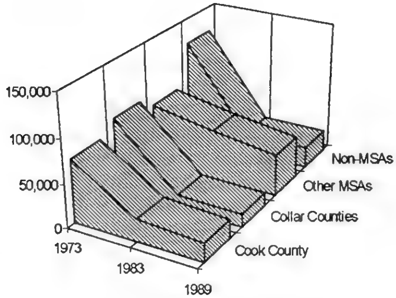

Figure 16. Emissions of nitrogen oxides (tons).

Hydrocarbon emissions were reduced overall by 45%, with the major decreases occurring in Cook County, and the Joliet, Peoria, and St. Louis MSA's. The Champaign and Decatur MSA's had the only substantial increases in HC emissions - at 87% and 376%, respectively. Emissions outside the metropolitan areas also increased substantially, up 65% from 1973 levels.

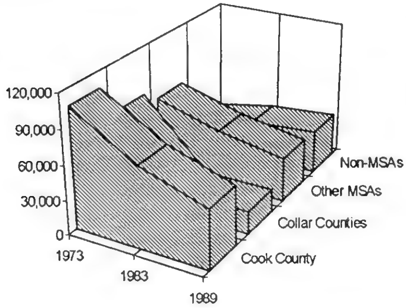

Figure 17. Hydrocarbon emissions (tons).

Carbon monoxide emissions decreased 59% statewide over this period. Most of the reduction, 76%, occurred in the Joliet MSA where CO emissions dropped from 132,000 tons (half of the statewide manufacturing total) to 7,000 tons. The bulk of the remaining decrease occurred in the St. Louis MSA. Emissions increased along with manufacturing activity in DuPage, Lake, and McHenry counties and the Decatur MSA. Emissions grew more than 500% in each of these areas.

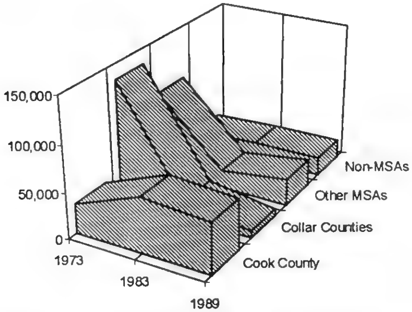

Figure 18. Carbon monoxide emissions (tons).

Pollution Control Efficiency Trends

Using manufacturing output and emissions figures, 'tons of emissions per million dollars of output' were calculated for each pollutant to determine trends in pollution control efficiency. Over the sixteen year period, emissions decreased for all criteria air pollutants, particularly particulates, down 87% from 4.1 to .52 tons of emissions per million dollars of output. Figure 19 illustrates efficiency gains by pollutant. Table 2 shows the result of the calculations for each pollutant, as well as percentage changes between the years studied.

Table 2. Emissions and Value of Output Linked

	Year 1973 1983 1989	Percentage Changes 1973-1983 1983-1989 1973-1989
Particulates (tons of emissions/ million $ of output)	4.10 0.72 0.52	-82.38% -27.70% -87.31%
SO_2 (tons of emissions/ million $ of output)	5.50 2.52 1.90	-54.28% -24.62% -65.54%
NO_X (tons of emissions/ million $ of output)	1.94 1.08 0.77	-44.00% -28.80% -60.13%
HC (tons of emissions/ million $ of output)	2.43 1.51 1.06	-37.79% -30.11% -56.53%
CO (tons of emissions/ million $ of output)	1.88 1.04 0.80	-44.51% -23.51% -57.55%

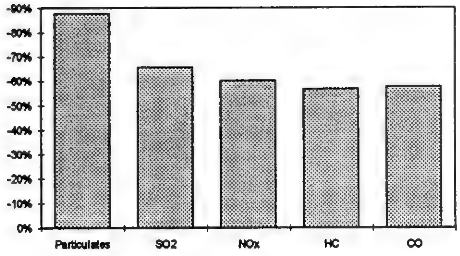

Figure 19. Percent reduction in tons of emissions per million dollars of output - 1973 through 1989.

CONCLUSION

The number of manufacturing establishments in Illinois slightly decreased between 1968 and 1989. Employment within these firms, however, saw a significant decline. The number of manufacturing employees statewide dropped from 1.42 million in 1968 to 1.04 million in 1989, a reduction of 27%. The value of manufacturing output, on the other hand, increased during this 21 year period. In 1987 dollars, output rose from $117 billion to $127 billion, an increase of almost 9%.

Within several counties and metropolitan statistical areas (MSA's), striking changes took place over the twenty years. Cook County and the Davenport/Rock Island/Moline and St. Louis MSA's experienced significant losses, with output in Cook County and the St. Louis MSA declining by 15% and in the Davenport/Rock Island/Moline MSA by 9%. In the collar counties, output increased, with DuPage County leading at 431%, followed by McHenry County at 183% and Lake County at 135%. In the university MSA's of Champaign/Urbana/Rantoul and Bloomington/Normal, both employment and output increased, with output up 358% and 171%, respectively.

Emissions data for 1973 through 1989, available from the IEPA shows that emissions of criteria air pollutants are down, particularly particulates. Emissions of particulates are down 87%; sulfur oxides, 67%; nitrogen oxides, 69%; hydrocarbons, 45%; and carbon monoxide, 59%. Emissions per dollar of output are also down, with particulates and sulfur dioxide again in the lead, illustrating gains in manufacturing efficiency.

TRANSPORTATION

The transportation category of CTAP consists of highway vehicles — trucks, buses, motorcycles and automobiles; rail carrier — passenger and freight; air travel — airplanes and jets; and water traffic — recreation and freight.

HIGHWAY VEHICLES

Within the transportation category, highway vehicles emit the majority of air pollutants, primarily nitrogen oxides (NOx), volatile organic compounds (VOCs) and carbon monoxide. The level of emissions depends on the vehicle miles traveled (VMT), the types of vehicles and their emission rates, the fuels used, the emissions standards set by government, and a variety of other factors. This section looks at trends in VMT, vehicle emission rates and highway emissions.

Vehicle Miles Traveled (VMT)

The number of vehicle miles traveled in Illinois has grown steadily during the past twenty years. Statewide VMT grew from 61 billion miles in 1973 to 86 billion miles in 1991, an increase of 41% (Figure 1). The only exceptions to this general pattern of growth are the 1974-75 and 1979-82 periods when rapid oil price increases and recessions stifled VMT growth. Despite the oil price "shocks" experienced during the 1973 - 1982 period, VMT grew 8%. When the real price of gasoline (corrected for inflation) declined between 1982 and 1991, VMT grew 30%, nearly 3% each year.

Figure 1. Illinois VMT: 1970 - 1991.

The rate of VMT growth in different parts of the state has varied significantly. During the 1973-82 period, when statewide VMT grew by 8%, the MSA's (urban areas) outside of the metropolitan Chicago area actually decreased travel while the Chicago collar counties, experiencing tremendous economic growth, increased VMT nearly 20%. In the 1982-1991 period, when statewide VMT grew 30%, VMT in the balance of the state (non-MSA counties) grew more slowly at 21%, while VMT in the Chicago suburbs grew by nearly 50%.

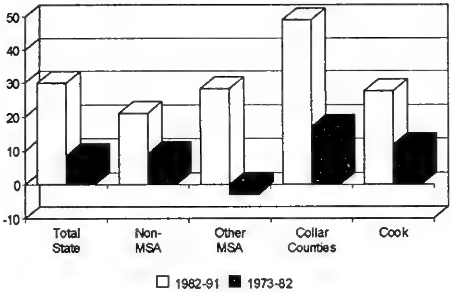

Figure 2. Percent change in VMT.

VMT by Vehicle Type and Fuel

Vehicle emissions depend not only on total miles traveled but also on the vehicle type and fuel used — diesel or gasoline. The number of miles traveled has increased for all vehicles except for motorcycles (Figure 3). Motorcycle VMT has consistently declined and currently represents only about 0.5% of annual travel. Light trucks and heavy trucks have increased VMT the most, about 3-5% per year (Table 1), reflecting increased household use of pick-up trucks and increased freight traffic by heavy trucks.

Diesel-powered vehicles have increased their VMT at double the rate of gasoline-fueled vehicles — 4% annually compared to 2% (Table 2). Rising diesel VMT is due to increased truck freight and domestic use of diesel-powered cars and light trucks.

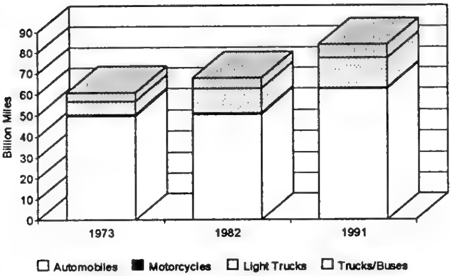

Figure 3. VMT by vehicle type[1].

Table 1. Annual Growth in VMT by Vehicle Type[1]

	1973-82	1982-91	1973-91
Automobile	0.2	3.1	0.2
Motorcycle	-1.4	-7.5	-3.9
Light Trucks	6.5	3.2	5.1
Trucks/Buses	1.6	4.4	2.7

Table 2. Annual Growth in VMT by Fuel[1]

	1973-82	1982-91	1973-91
Diesel	2.8	5.5	3.9
Gasoline	1.0	3.0	1.8

Vehicle Emission Rates

Vehicle emission rates depend on several factors, including emission standards, vehicle age and maintenance history, condition of emission controls, and ambient temperature and traffic conditions. Average emission rates can be estimated using federal government emission standards (Table 3) and vehicle turnover rates.

NOx. The NOx emission rates for gasoline cars and light trucks, the two largest categories of highway vehicles, are about one-half of what they were in 1973 (Figure 4). Since catalytic converters became standard in 1983 rates have dropped substantially. Progress should continue as older vehicles are replaced.

Heavy trucks, both gasoline and diesel, emit NOx at rates 3-7 times that of autos. Although recent emission controls will reduce this rate as older trucks are replaced, overall NOx emissions will remain high compared to light vehicles because truck standards are 5-10 times higher than car standards.

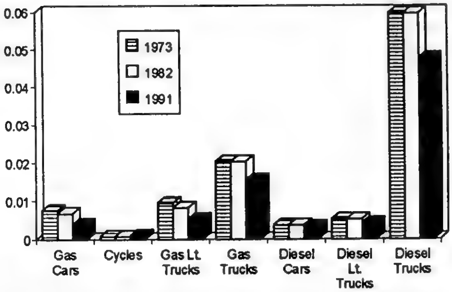

Figure 4. Average NOx emission rates (pounds per mile)[2].

VOCs and CO. Emission standards for VOCs and CO were imposed much sooner than they were for NOx. Because of these standards, the average emission rates for cars and light trucks have steadily improved since 1973, resulting in a 75% emission reduction over the last 18 years. Standards for gasoline-powered heavy trucks, which emit both VOCs and CO at high rates, were not imposed until 1983 (see Figure 5 and 6). Strengthened in 1991, the truck standards should continue to reduce VOC emissions in the future.

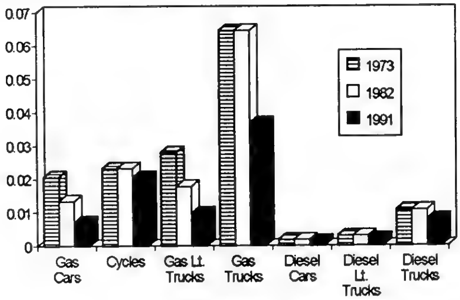

Figure 5. Average VOC emission rates (pounds per mile)[2].

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[1] Estimated from U.S. Department of Commerce, Census of Transportation; U.S. Department of Transportation, Highway Statistics; Oak Ridge National Laboratory, Transportation Energy Data Book; Illinois Department of Transportation, Illinois Travel Statistics; Illinois Department of Revenue, Motor Fuel Tax Gallonage; and Illinois Secretary of State, Vehicle Registrations; for various years.

Table 3. Federal Emission Standards by Vehicle and Fuel Type (pounds/mile)

Gasoline Passenger Cars

Year	NOx	VOC	CO
1990	0.0018	0.0023	0.0111
1983	0.0018	0.0024	0.0111
1978	0.0056	0.0062	0.0461
1972	0.0070	0.0112	0.0844
1963	0.0076	0.0225	0.1441

Light-duty Gasoline Trucks

Year	NOx	VOC	CO
1990	0.0024	0.00266	0.0166
1983	0.0035	0.00415	0.0327
1978	0.0057	0.00690	0.0431
1972	0.0100	0.01610	0.1022
1963	0.0093	0.03030	0.1581

Diesel Passenger Cars

Year	NOx	VOC	CO
1991	0.0023	0.0010	0.0031
1983	0.0033	0.0010	0.0031
1968	0.0036	0.0018	0.0038

Heavy-duty Diesel Vehicles

Year	NOx	VOC	CO
1991	0.0178	0.0045	0.0241
1983	0.0424	0.0060	0.0294
1968	0.0596	0.0106	0.0303

Motorcycles

Year	NOx	VOC	CO
1990	0.0019	0.0078	0.0468
1972	0.0007	0.0231	0.0844

Heavy-duty Gasoline Vehicles

Year	NOx	VOC	CO
1991	0.0094	0.00557	0.0299
1983	0.0122	0.01790	0.1427
1968	0.0203	0.06440	0.5078

Light-duty Diesel Trucks

Year	NOx	VOC	CO
1990	0.0027	0.0015	0.0035
1983	0.0037	0.0015	0.0035
1978	0.0051	0.0029	0.0057

Note: The earliest period for each category represents uncontrolled emissions. Source: USEPA, State Workbook: Methodologies for Estimating Greenhouse Gas Emissions, Nov. 1992.

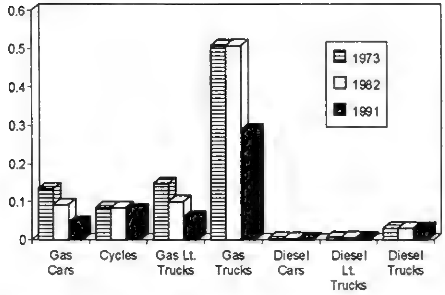

Figure 6. Average CO emission rates (pounds per mile)[2].

Vehicle Emissions

Highway vehicle emissions are largely a function of the emission rates of each type of vehicle and the miles traveled by each. Even though VMT grew more than 40% between 1973 and 1991, vehicle emission rates improved enough to offset VMT and reduce overall emissions of all three pollutants. Carbon monoxide emissions declined from 4.3 to 2.3 million tons and VOCs dropped from 675,000 to 360,000 tons (Figure 7). In both cases, emissions fell by more than 45%. Over the same period NOx emissions fell from 300,000 to 275,000 tons, a drop of only 8%. Trends for each pollutant are discussed below.

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[2] Calculated from USEPA, State Workbook: Methodologies for Estimating Greenhouse Gas Emissions, Nov. 1992; U.S. Department of Commerce, Illinois Census of Transportation, various years; and IEPA, An Analysis of the Low Emission Vehicle Program in Illinois, July 1992. The calculated emission rates are estimates of actual emissions rates. Stedman and Bishop (An Analysis of On-road Remote Sensing as a Tool for Automobile Emissions Control, for ENR, March 1990) measured actual CO emission rates from passenger vehicles to be about 18 percent more than that calculated. Similarly, Stedman et al (On-road Carbon Monoxide and Hydro carbon Remote Sensing in the Chicago Area, for ENR, October 1991) measured actual VOC rates to be slightly higher than the calculated rates (when taking into account evaporative and other non-exhaust emissions). The measurements reflect remote-sensing data at a single site for a few consecutive days in 1989 and 1990.

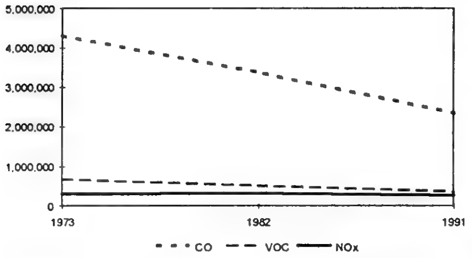

Figure 7. Vehicle emissions statewide (tons)[3].

Nitrogen Oxide (NOx)

Initial standards for nitrogen oxide were not much lower than the level of uncontrolled emissions, with the result that emissions increased slightly between 1973 and 1982. In response to stricter NOx standards imposed in 1983, emissions fell 13% over the last eight years. Most progress has been in gasoline-powered vehicles. Conversely, emissions from diesel-powered vehicles jumped 33% since 1973 because more diesel passenger vehicles are being sold and heavy truck traffic has increased substantially (Figure 8). NOx emissions from diesel have grown from 23% of total highway NOx in 1973, to 34% in 1991.

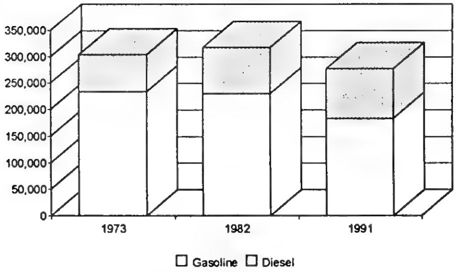

Figure 8. NOx emissions (tons) by fuel[3].

Progress in reducing NOx emissions varies across the state (Figure 9). During the 1973-82 period, when emissions grew only 5% statewide, they jumped 10% in the Chicago collar counties. The difference was due to the rapid population and economic growth in collar counties and the resulting growth in VMT. In the other MSAs, emissions actually declined between 1973 and 1982 because of the economic recessions.

In the 1982-1991 period, stricter controls caused NOx emissions to decline throughout the state. Cook County showed the largest decrease, about 18%. The other MSAs and non-MSA counties reduced emissions by an average of 13-15%. The area of greatest growth, the Chicago collar counties, reduced NOx the least, by a mere 2%.

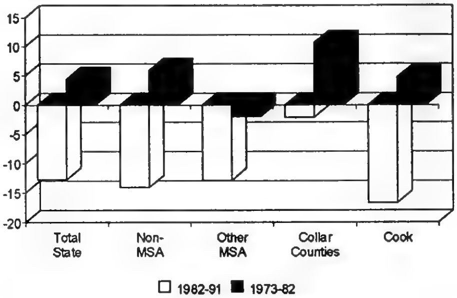

Figure 9. Percent change in NOx emissions[4].

Volatile Organic Compounds

Volatile Organic Compound (VOC) emissions have fallen steadily since 1973, the year after standards were imposed for gasoline-fueled automobiles and light trucks. Diesel emissions, although only a small percentage of total VOC emissions, have continued to grow and are now 25% higher than they were in 1973 (Figure 10).

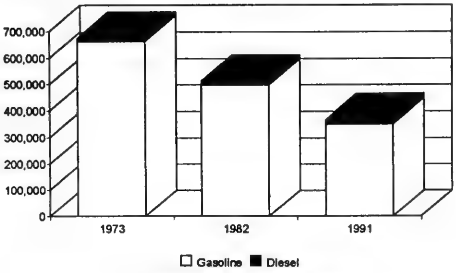

Figure 10. VOC emissions (tons) by fuel[3].

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[3] Calculated from average emission rates (see footnote 2) and VMT by type of vehicle (see footnote 1).

[4] County emissions were estimated by splitting VMT by county (IDOT, Traffic Characteristics on Illinois Highways) into vehicle type based on county population (Census of Population), miles of interstate highway (IDOT), and statewide vehicle shares (see footnote 1) and applying emission rates by vehicle type (see footnote 2).

In most parts of the state, VOC emissions declined 25-30% during each of the past two decades, or 40-50% over 18 years (Figure 11). In the collar counties, emissions declined 20% during each period and 33% over the entire period.

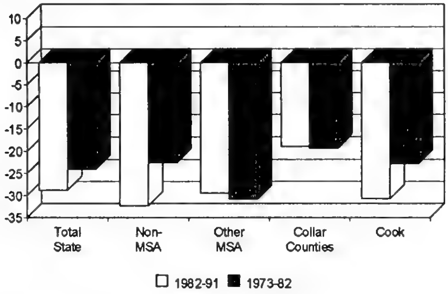

Figure 11. Percent change in VOC emissions[4].

Carbon Monoxide

Similar to VOCs, carbon monoxide (CO) emissions have declined steadily since 1973 due to strict federal standards. CO emissions are now only 55% of 1973 levels (Figure 12). At the same time, emissions from diesel-fueled vehicles grew 60% and now account for 2.5% of highway CO, up from less than 1% in 1973.

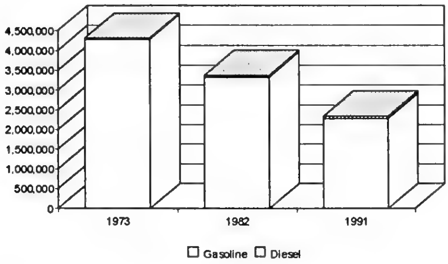

Figure 12. CO emissions (tons)[3].

The geographic patterns of carbon monoxide emissions are similar to those of VOC emissions (Figure 13). From 1973 to 1982, CO emissions declined more than 20% statewide, about 17% in the collar counties and about 29% in other MSAs. Between 1982 and 1991, emissions declined 30% in most of the state, but only about 20% in suburban Chicago.

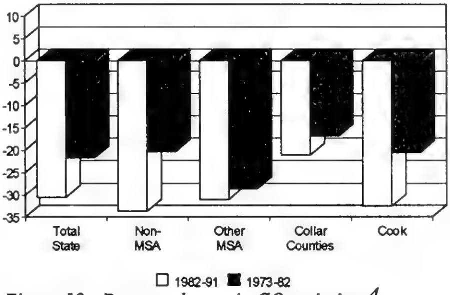

Figure 13. Percent change in CO emissions[4].

Highway Summary

During the past two decades, Illinois has significantly reduced highway emissions of VOCs and carbon monoxide. During the past decade the state has also moderately reduced emissions of NOx. These reductions occurred in spite of rapid increases in VMT in many parts of the state (Figure 14). Progress will continue as older cars and trucks are replaced by those meeting the latest emission standards, but will probably moderate as more vehicles on the road meet these standards. Consequently, growing VMT may eventually outstrip the ability of vehicle emission standards to bring down highway emissions.

Emissions from heavy trucks and diesel vehicles increasingly contribute to highway emissions in the state. This is particularly a problem with NOx, since NOx emission rates from heavy trucks are relatively high. New standards (1991) for gasoline-fueled heavy trucks should reduce some emissions, but, unless the growth of diesel vehicles and diesel freight slows down, diesel vehicles are likely to continue producing a larger share of highway emissions.

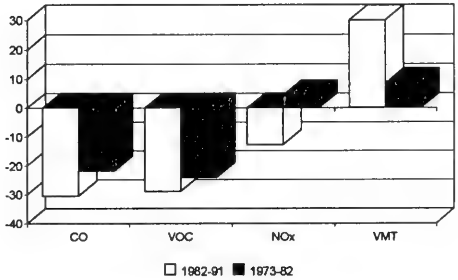

Figure 14. Percent change in VMT and highway emissions.

Highway emission trends have varied around the state, depending on the local growth in VMT. Typically, the more rural counties have had the least growth in vehicular travel and thus the most improvement in air emissions. Urban areas, particularly the Chicago collar counties, continue to have significant growth in VMT and thus have had the least improvement in air emissions. If VMT continues to grow, highway emissions could increase within a few years, reversing the trend of decreasing air emissions.

RAILROADS

Illinois is served by rail carrier systems that extend to the east, west and Gulf coasts as well as to Canada and Mexico (Figure 15, next page). Forty-six railroad companies operate in the state, loading and delivering a diversity of products. Chicago's Union Station is home of Amtrak's national hub and is a major transfer point for regional and transcontinental passenger routes. Chicago is also served by 11 commuter rail lines which have 230 stations in the metropolitan area.

Except for two electric commuter lines in the Chicago area, virtually all trains in Illinois are pulled by diesel-powered locomotives. Relative to highway vehicles, emissions from these engines are small, but they do emit volatile organic compounds (VOCs), nitrogen oxides (NOx), carbon monoxide (CO), and, to an even lesser degree, sulfur oxides and particulates. The following sections discuss trends in Illinois track mileage, fuel use, and emissions for the years 1973 - 1991.

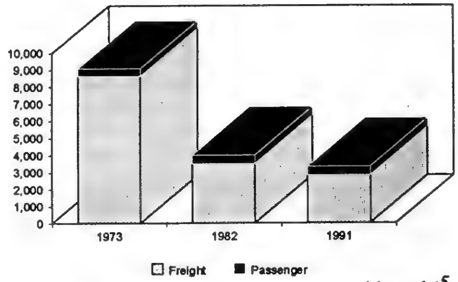

Figure 16. Fuel use by railroads (thousand barrels)[5].

Fuel Use and Track Mileage

From 1973 to 1982, rail fuel use fell by more than 50%; in the next nine years it declined an additional 17%. Over the 18-year period annual fuel use dropped from 9 million to 3.3 million barrels of diesel. Most of this drop was due to the rail companies' loss of freight shipments to the trucking industry. While fuel use by freight rail declined, fuel use by passenger rail remained relatively steady, around 0.5 million barrels.

The amount of Illinois track has declined along with fuel use (Figure 17). Approximately 20% of track mileage has been abandoned during each of the last two decades, totaling nearly 9,000 miles since 1973.

The track mileage in each county provides a rough approximation of rail fuel consumption (and thus emissions) within each county.[6] Although railroads have abandoned track in all parts of the state, they have done so more quickly in Cook County which accounted for 28% of track miles in 1973 but only 21% by 1982. Subsequently, track mileage in rural counties increased from 40% to 47% of total mileage.

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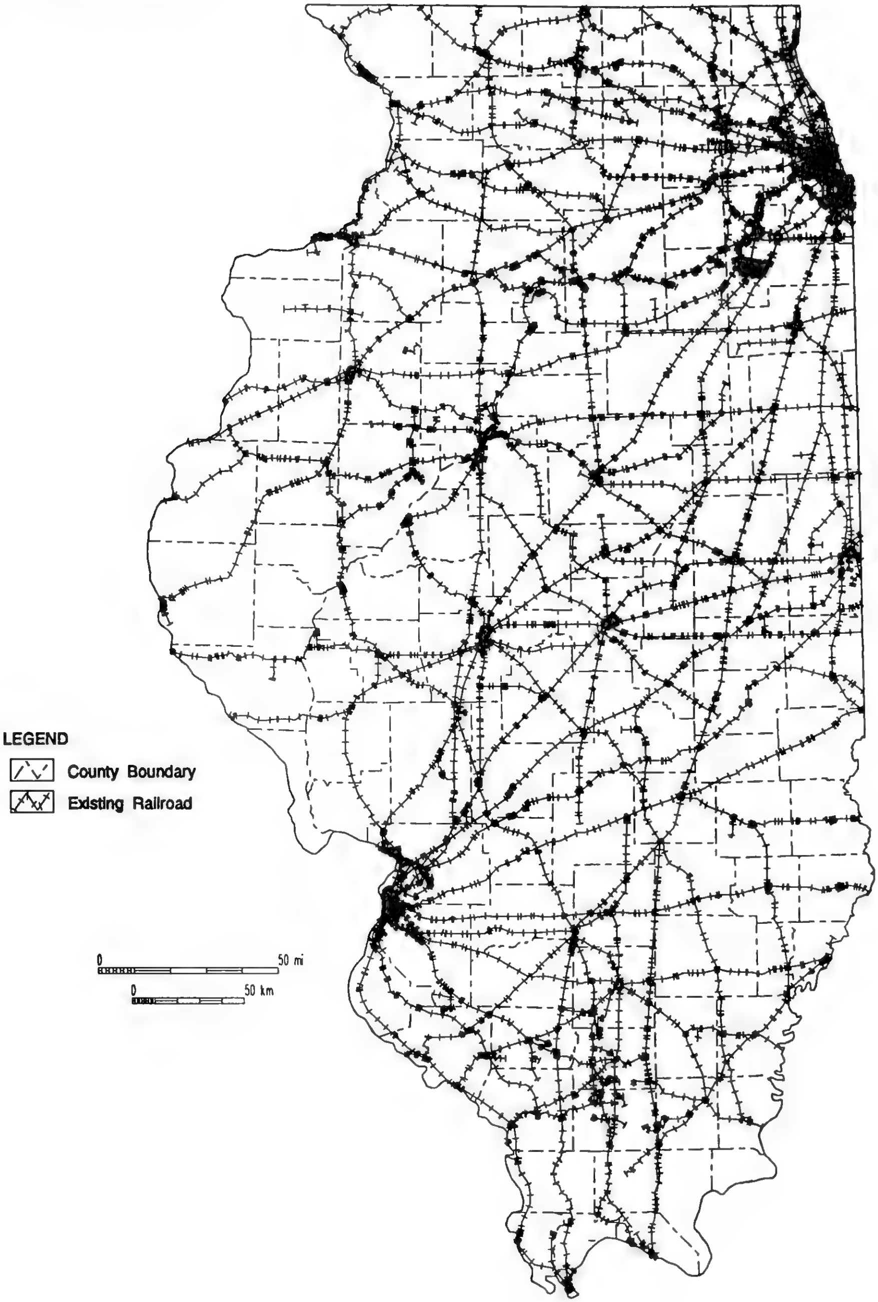
[5] Energy Information Administration, USDOE, *Fuel Oil and Kerosene Sales*, selected years; EIA, USDOE, *Petroleum Marketing Annual*, selected years; and Hooker, Rose and Greene, Oak Ridge National Laboratory, for USDOE, *End Use Energy Consumption Data Base: Transportation Sector*, 1980.

[6] IEPA, *1990 Ozone Precursors Emissions Inventory for the Chicago Area, Illinois Ozone State Implementation Plan*, October 1992.

Figure 15. Illinois Railroads.



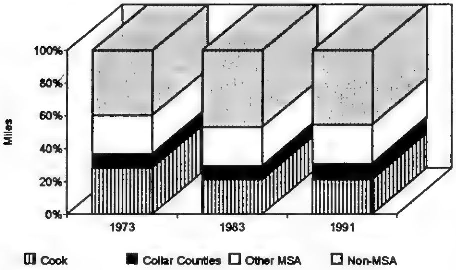


Figure 17. Track mileage by region[7].

Emissions

Diesel locomotives emit Nox, CO and VOCs at the rates given in Table 4.

Table 4. Diesel Locomotive Emission Rates[8].

	NOx	CO	VOC
Pounds/Million Btu	2.67	0.94	0.68
Pounds/Thousand Gallons	370	130	94

Emissions of all three pollutants have fallen during the last two decades, reflecting the decline in rail fuel use (Figure 18). Emissions of NOx have fallen from 70 thousand tons in 1973, to approximately 25 thousand tons in 1991. Similarly, emissions of both CO and VOCs have dropped from 18-25 thousand tons to 10 thousand tons.

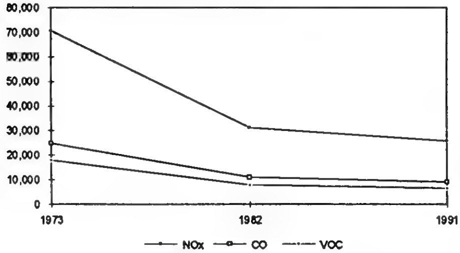


Figure 18. Railroad emissions (tons).

Railroad Summary

Since 1973, railroads have decreased their emissions of nitrogen oxides, carbon monoxide and volatile organic compounds by nearly two-thirds, due largely to the decline in rail's share of freight shipments. Overall, railroads are a relatively minor source of these pollutants; highway vehicles emit 100 times as much. Railroads do, however, contribute to pollution in major metropolitan areas, particularly Chicago and East St. Louis where ozone violations are a problem during hot weather.

AIR TRAVEL

Air travel is the second most significant source of emissions in the transportation category. Aviation gasoline, which accounts for less than 1% of transportation energy, and jet fuel, which accounts for 11% of transportation energy, emit four major pollutants: NOx, CH_4, VOC, and CO.

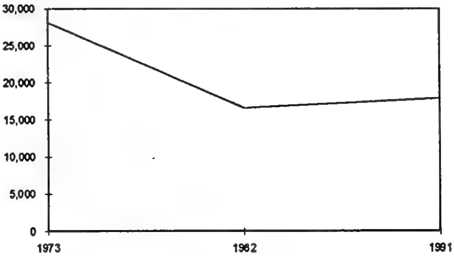


Figure 19. Jet fuel use (million barrels).

Fuel Use

Illinois is served by 75 public airports, 54 private airports and 14 public heliports (Figure 20). Regularly scheduled airline service is offered at 16 of the airports. Also, there are 722 designated landing areas associated with farms and other agricultural operations.

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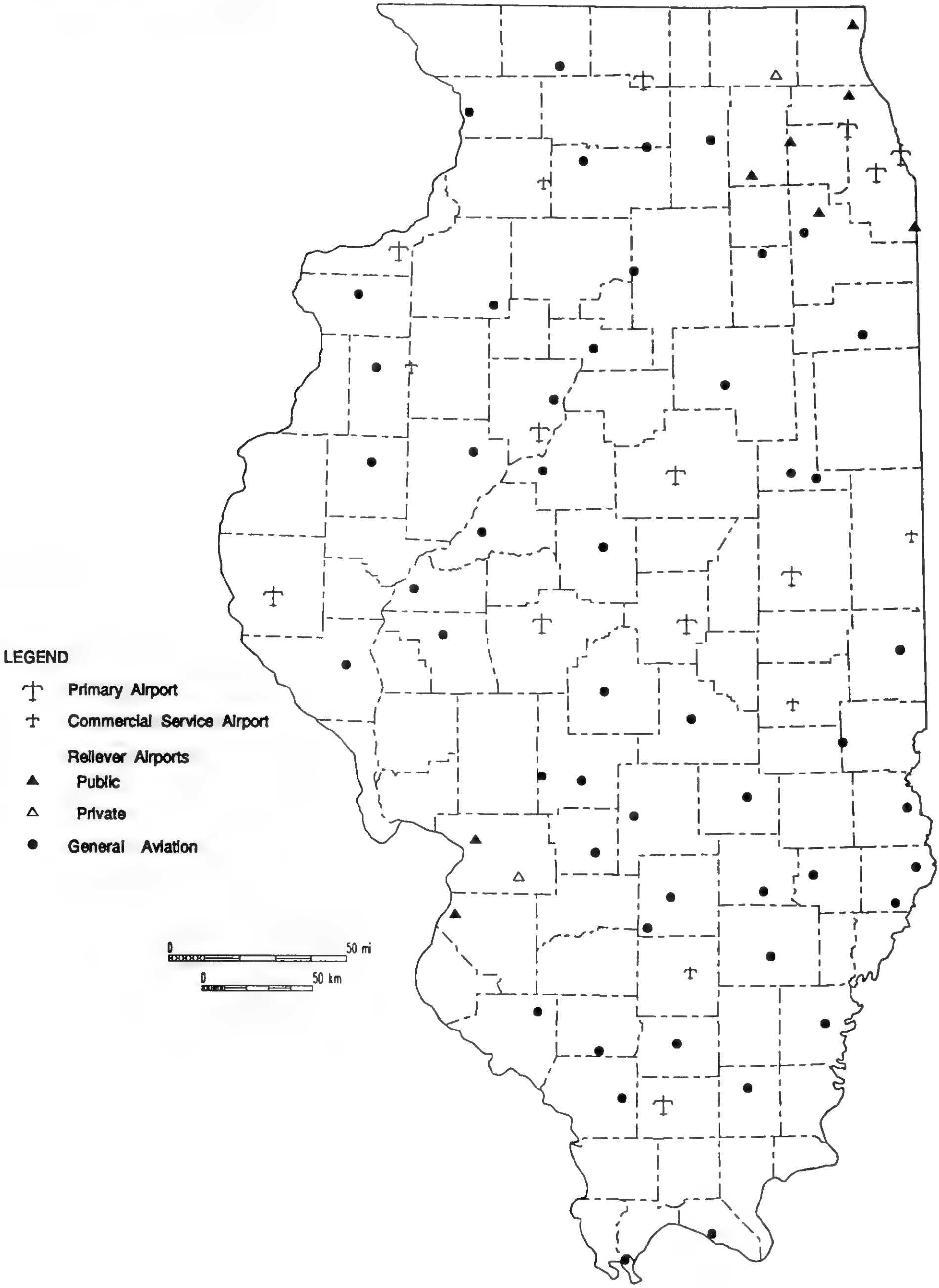
[7] Illinois Department of Revenue, *Certification of Assessment of Railroad Properties*, selected years

[8] The transportation category of CTAP consists of highway vehicles — trucks, buses, motorcycles and automobiles; rail carrier — passenger and freight; air travel — airplanes and jets; and water traffic — recreation and freight.

Figure 20. Illinois airports.



Chicago's O'Hare International Airport continues to be one of the busiest airports in the world; enplanements have grown 42% since 1984, and 86% of Illinois' passengers pass through the airport. Overall, Cook County accounts for 96% of the state's aviation fuel use, nearly all of it jet fuel. Most of the aviation gasoline, used in small airplanes, is burned downstate.

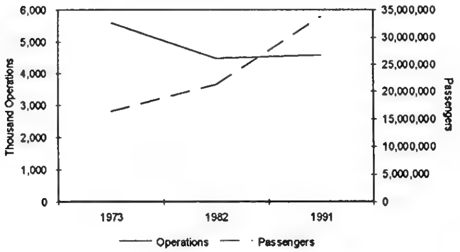


Figure 21. Number of passengers and airport operations.

Take-offs and landings (operations) have dropped over time while passengers flown (enplanements) have increased (Figure 21), indicating increased efficiency and size of commercial airplanes.

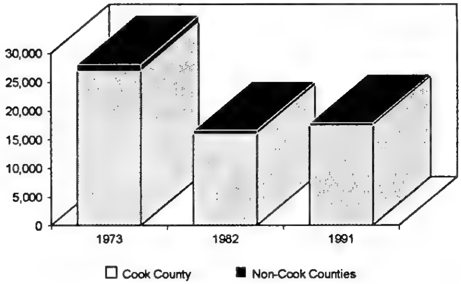


Figure 22. Jet fuel usage (thousand barrels).

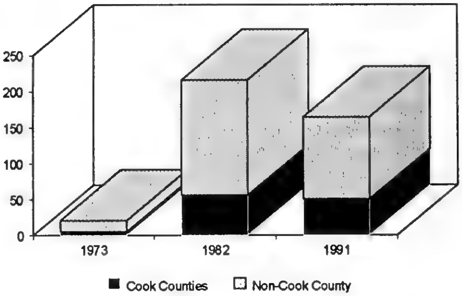


Figure 23. Aviation gasoline usage (thousand barrels).

Emissions

Emission rates for NOx, CO and VOC, given in Table 5, show that jet fuel emits more NOx while aviation gasoline emits more VOC and CO. Compared to NOx and CO, however, VOC's are fairly insignificant air fuel pollutants. NOx emissions, almost exclusively emitted by burning jet fuel, dropped considerably between 1973 and 1982, about 40%. Since then they have remained stable at 30 thousand tons. CO emissions have jumped more than 50% since 1973, with the increase emitted primarily by burning aviation gasoline.

Cook County is by far the primary source of aviation air emissions in Illinois, although air fuel use in some downstate counties emit a sizable amount of pollutants.

Table 5. Air Fuel Emissions Rates. (pounds/ton of fuel)

	NOx	CO	VOC
Jet Fuel	25.0	10.4	1.6
Aviation Gasoline	7.0	2068.0	48.0

Source: USEPA, States Workbook: Methodologies for Estimating Greenhouse Gas Emissions, November 1992

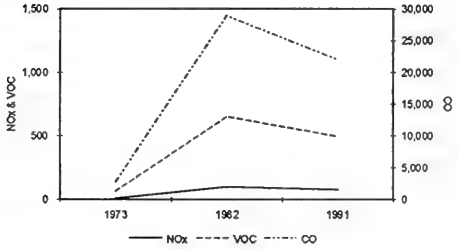


Figure 24. Aviation gasoline emissions (tons).

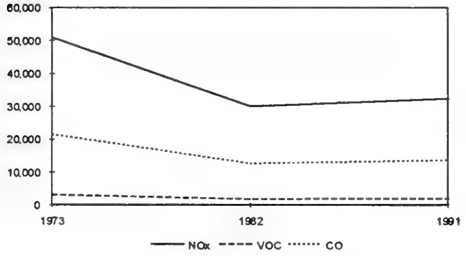


Figure 25. Jet fuel emissions (tons).

WATER TRAFFIC

Bordered on three sides by rivers and Lake Michigan, with 1,110 miles of navigable waterways, Illinois has the second largest commercial navigation system among all the inland states (Figure 26).[9] The 63 miles of Lake Michigan shoreline provide access to the Atlantic Ocean via the Great Lakes/St. Lawrence Seaway System, and the nearly 1 million acres of the lake which lie within the state's boundaries provide valuable water recreation. Almost 3,000 lakes — larger than six acres — and 3,200 miles of streams provide additional water recreation.[10]

Water traffic in Illinois can be broken down into two categories: freight shipping on navigable waterways and recreational boating on lakes and streams. Freight traffic predominantly burns diesel fuel and recreational craft burn mostly gasoline. Both emit NOx, VOC, and CO, as well as small amounts of CH_4 and N_2O. Compared to highway emissions, emissions from water traffic are not large, but they are not insignificant.

Fuel Use and Freight Shipments

Over the past 18 years, fuel use by freight traffic has declined somewhat while fuel use by recreational craft has grown, reflecting trends in the activity of each (Figure 27).

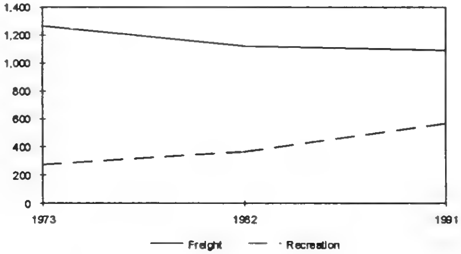


Figure 27. Fuel use by water traffic (thousand barrels).

The decline in freight traffic has been centered in the Chicago area. Total shipments and receipts from Illinois' primary deep-draft port have declined 74%, from 21.4 million tons in 1974 to 5.6 million tons in 1988. Much of the loss can be attributed to the declining need for lake coal boats to transport iron ore and coke to feed the steel mills in south Chicago. However, barge traffic in the river and canal waterway system is up 13% over the last 20 years. Thus, overall freight fuel use in the state declined only slightly, by about 15% since 1973.

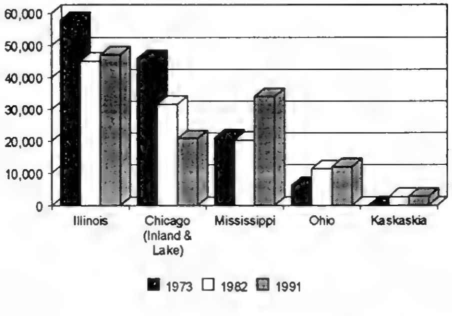


Figure 28. Illinois water traffic (thousand tons).

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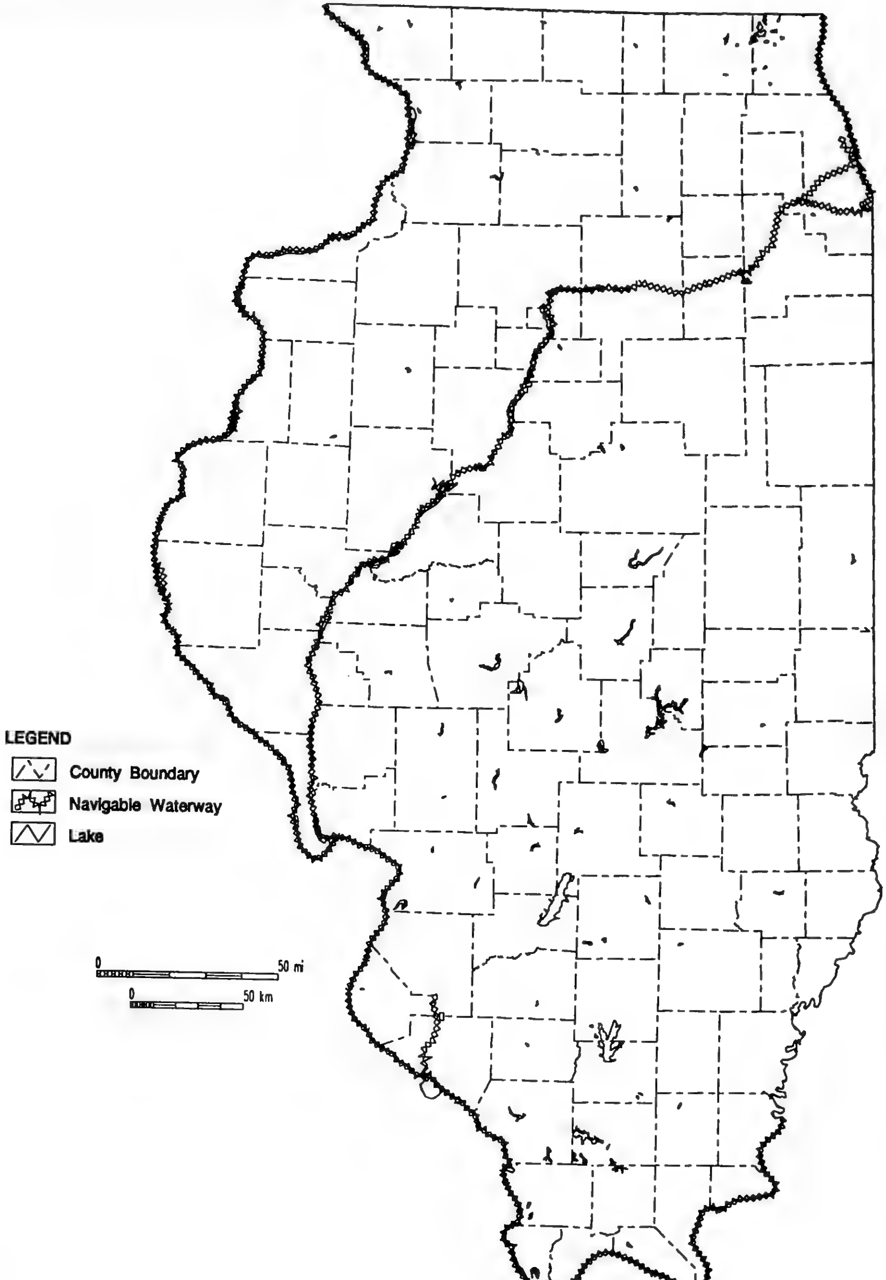
[9] Illinois Department of Transportation, *Directory of Lake and River Terminals in Illinois,* June 1982.

[10] Illinois Natural History Survey, Illinois Department of Energy and Natural Resources, *The Natural Resources of Illinois,* 1987.

Figure 26. Navigable waterways and lakes.



Since most water shipping is localized along major waterways outside the metropolitan areas, most of the freight fuel consumption, 66%, occurs in rural counties. Cook County and the collar counties consume about 13% because of their high rate of economic activity and their proximity to Lake Michigan (Figure 29).

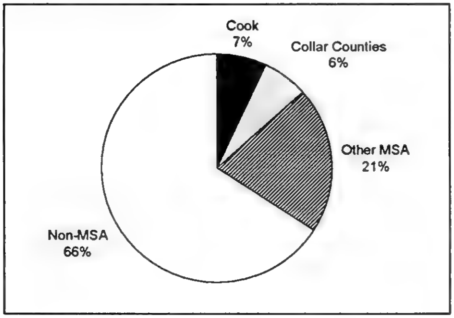


Figure 29. Freight fuel use by region 1991. Consumption is based on miles of waterway per county and shipments on major waterways.

Recreational boat activity during the past two decades has grown steadily, with the number of registered water craft growing more than 25% in the last five years. Since 1973, gasoline fuel use has nearly doubled. Based on registrations, recreational boat fuel use is fairly well distributed throughout Illinois (Figure 30).

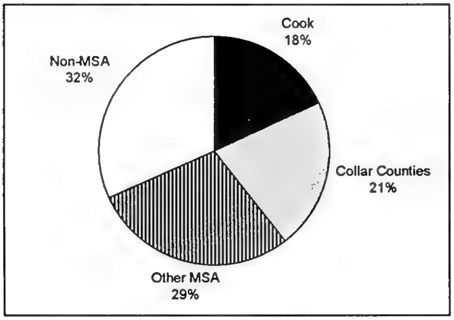


Figure 30. Recreational boat fuel use by region 1991. Consumption is based on boat licenses and population per county.

Emissions

The emission rates for boat traffic are given in Table 6. Freight-bearing craft have the highest NOx emission rates, while recreational craft have the highest rates for VOCs and CO.

Table 6. Boat Traffic Emission Rates. (lbs/1000 gal.)

	NOx	CO	VOC
Freight	278	101	51
Recreation	102	2222	615

Source: IEPA, Illinois State Implementation Plan, November 1992

Nitrogen oxide emissions have declined only 5% since 1973. Most NOx emissions are from freight, and the decline in Lake Michigan freight more than offset the doubled NOx emissions from recreational craft. Recreation emissions have grown from 8% to 16% of total water traffic NOx. (Figure 31).

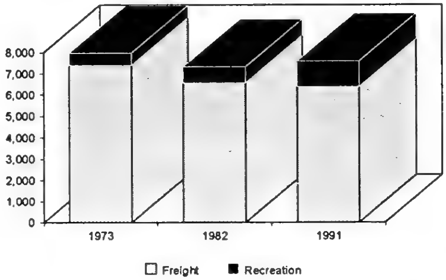


Figure 31. Water traffic NOx emissions (tons).

Emissions of **volatile organic chemicals** have jumped 70%, primarily from recreational boating. Emissions have climbed from less than 5,000 tons per year in 1973 to nearly 8,500 tons in 1991 (Figure 32).

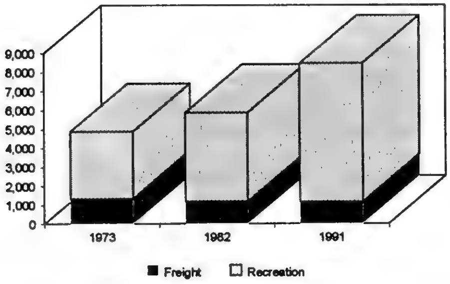


Figure 32. Water traffic VOC emissions (tons).

Because of its high emission rate from recreational craft, **carbon monoxide** is the most significant water craft pollution. Emissions have grown 90 percent (Figure 33) during the past two decades.

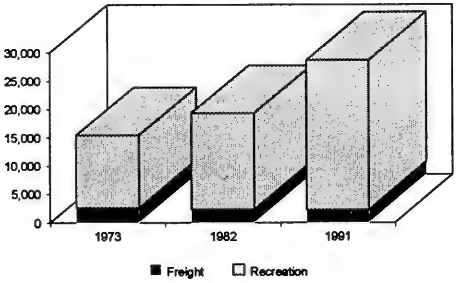


Figure 33. Water traffic CO emissions (tons).

Water Traffic Summary

Trends in water traffic emissions differ from emission trends in the other transportation categories. The foremost difference is that CO and VOC emissions from water traffic are growing, whereas they are declining in the other transportation modes. The downward trend in other modes occurred primarily because of emission standards, improved energy efficiency, or, in the case of railroads, shifts to other modes of transportation. These factors did not significantly affect water traffic.

For example, water emissions of carbon monoxide are high relative to NOx and VOCs. In the highway sector, strict CO regulations were imposed to reduce urban pollution. Water CO emissions, on the other hand, are a rural problem. Freight emissions occur in counties bordering the navigable waterways — the Illinois, Ohio, Kaskaskia and Mississippi rivers — and most recreation emissions occur in rural areas.

CONCLUSION

Four major modes of transportation — highway, rail, air, and water — emit significant quantities of NOx, VOCs and CO. In 1991, highway vehicles accounted for about 80% of NOx emissions and for more than 95% of VOCs and CO from transportation sources (Figure 34). Water transportation emitted the smallest amount of pollutants, followed by rail and air transportation. While cars and light trucks emit 80% of the VOCs and CO, they emit less than 50% of NOx. Heavy trucks, rail, and air travel are all major sources of NOx.

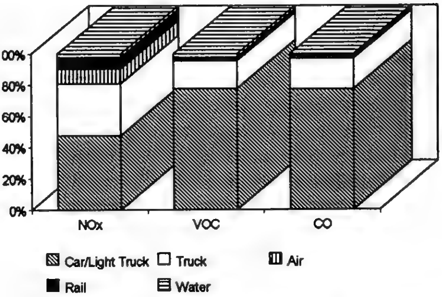


Figure 34. Share of 1991 transportation emissions by mode.

Total transportation emissions dropped significantly between 1973 and 1991, with a 20% decrease in NOx and a 45% decrease in VOCs and CO (Figure 35). This occurred despite tremendous growth in most transportation activity. Highway miles traveled grew by more than 40% during this time period, while both the number of air passengers and recreational boating grew by 100%. (Only rail travel and marine freight showed moderate decreases in activity.) The drop in emissions can be accounted for by increasingly strict emission standards for cars and light trucks. In certain transportation modes, however, emissions have increased — NOx is up from trucks, VOCs are up from water traffic, and CO is up from both air and water travel. The growth in emissions in these cases reflects the rapid growth in truck traffic, recreational boating, and general aviation.

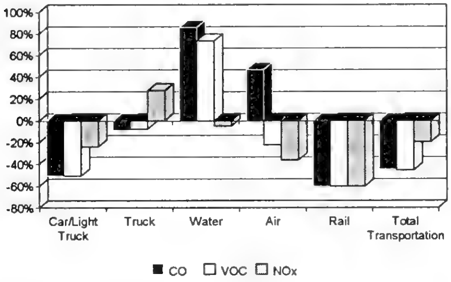


Figure 35. Percent change in transportation emissions from 1973-91, by mode.

On a geographic basis emissions have uniformly decreased, with the major exception of the Chicago collar counties (Figure 36). While VOC and CO emissions around the state dropped by nearly half between 1973 and 1991, they only decreased by about one-third in the collar counties. NOx emissions actually increased slightly in the collar counties, compared to a more than 20% decrease in the rest of the state. This reflects the rapid economic growth that has occurred in suburban Chicago in the last twenty years.

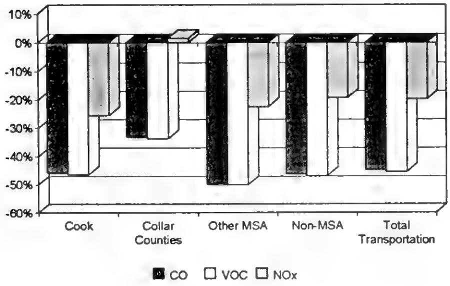


Figure 36. Percent change in transportation emissions from 1973-91, by region.

A final trend that deserves further discussion is the increasing dependence on heavy trucks to move freight. During the last twenty years deep draft shipments on the Great Lakes have declined by 75% and rail activity (measured by fuel use) has dropped by 60%. Barge shipments have remained steady or increased only slightly. Vehicle miles traveled by heavy trucks, however, have actually increased by nearly 100%.

The displacement of barges and rail by trucks has resulted in higher air emissions from freight transportation (Table 7). Trucks consume eight times as much energy per ton-mile of freight as barge or rail. Taking into account the respective emission factors for each transportation mode, trucks emit 3 to 70 times as much air pollutants per ton-mile as barges or rail. Barges are the most efficient, followed closely by rail. The discrepancy between truck and the other freight modes is not as great when taking into account the value of shipments. The value of truck freight from manufacturing establishments, for example, is approximately three times that of barge and rail freight.

Table 7. Efficiency of Freight Shipments by Mode of Transportation[11].

Freight Mode	Barge	Rail	Truck
Btu/ton-mile	403	427	3483
$/ton-mile	$1.32	1.41	3.99
(lb/1000 ton-miles) NOx VOC CO	 0.81 0.15 0.29	 1.70 0.12 0.58	 5.14 3.08 21.42
(lb/$1000) NOx VOC CO	 0.61 0.11 0.22	 1.20 0.09 0.41	 1.29 0.77 5.37

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[11] Efficiency per ton mile is from American Waterways Operators, *Impact of the Proposed Inland Waterway User Fuel Tax Increase on the Inland Water Transportation Industry*, March 1993. Dollars per ton-mile is from U.S. Department of Commerce, *Commodity Transportation Survey*, 1977.

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ELECTRICITY GENERATION

In 1991, 88 electric utilities operated in Illinois, generating electric energy from nuclear fuel (uranium) or from burning fossil fuels (natural gas, coal, and oil). A small percentage of electricity is generated through other sources such as hydro power (falling water) or co-generation (using waste energy to produce electricity); however, these sources are not discussed in this report.

Once generated, electricity is transmitted through power lines with the help of a transformer, an electromagnetic device which changes the voltage of alternating current. The electricity is transmitted to substations, where the voltage is switched/regulated, and on to the end use point. About 70% of the original energy is lost during the generation, transmission and distribution process. Hence only 30% is actually consumed by the end user (Illinois Energy Plan, 1982).

The environmental impacts of electricity generation considered in this report are air pollution, solid waste and nuclear waste. Electricity transmission can also have a negative impact — on agricultural production, particularly when the transmission lines interfere with machinery, and on communications, aviation, television and radio signals. In recent years, concerns have been raised about the health effects of exposure to high voltage operations (Allison, June 1988). However, these impacts are not discussed in this report.

CUSTOMER CLASSES

The three main groups of electricity customers are residential, commercial and industrial. Residential customers are by far the largest group; by year end 1991, their numbers reached slightly more than four million customers (4,021,332), or approximately 91% of the total. Commercial customers are the second largest group and industrial the smallest. However electric consumption numbers are reversed, with the industrial class consuming the most electricity, followed by commercial, and then the residential class.

Residential customers are those who consume electricity for domestic purposes. The number of residential customers grew at an annual compound rate of 4.01% per year from 1970 to 1991. Most of the growth was experienced between 1970 and 1975 and between 1975 and 1980 when growth increased 9.2% and 7.4% respectively. Residential consumption grew at an annual compound rate of 4.6% per year from 18.2 billion kilowatt-hours (kWh) in 1970, to 31.9 billion kWh[1] in 1991, a 74.4% increase. Residential energy consumption grew during the seventies due to the increasing ownership of electric appliances, particularly air-conditioners. By 1980, air conditioner use in the service territory of the four major investor-owned utilities ranged between 68-90% of existing homes.

Commercial customers are businesses included in the Standard Industrial Classification (SIC) codes 50 - 89 (U.S. Dept of Commerce). Typically, commercial customers use more electricity than their residential counterparts; however, customer consumption fluctuates depending on the level of business activities. Statewide, commercial customers grew from 335,673 in 1970 to 415,960 by 1991, a 23% increase. Statewide commercial consumption in 1970 was 17.6 billion kWh and grew to 30.9 billion kWh in 1991, a 76% increase. The most significant peaks were in 1972 and in 1987 when annual commercial consumption increased 7% and 6% respectively, from previous years.

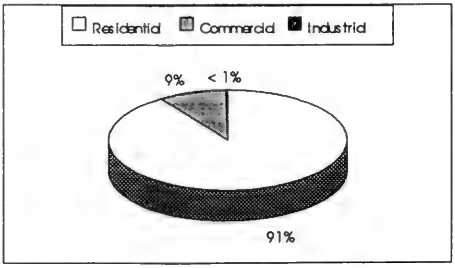

Figure 3. Percent distribution of customer classes, 1991.

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[1] Kilowatt-hour is equal to one thousand (1,000)watt-hours; a megawatt-hour is equal to one million (1,000,000) watt-hours and, a gigawatt-hour equals one billion (1,000,000,000) watt-hours.

Figure 1. Illinois electric utilities.

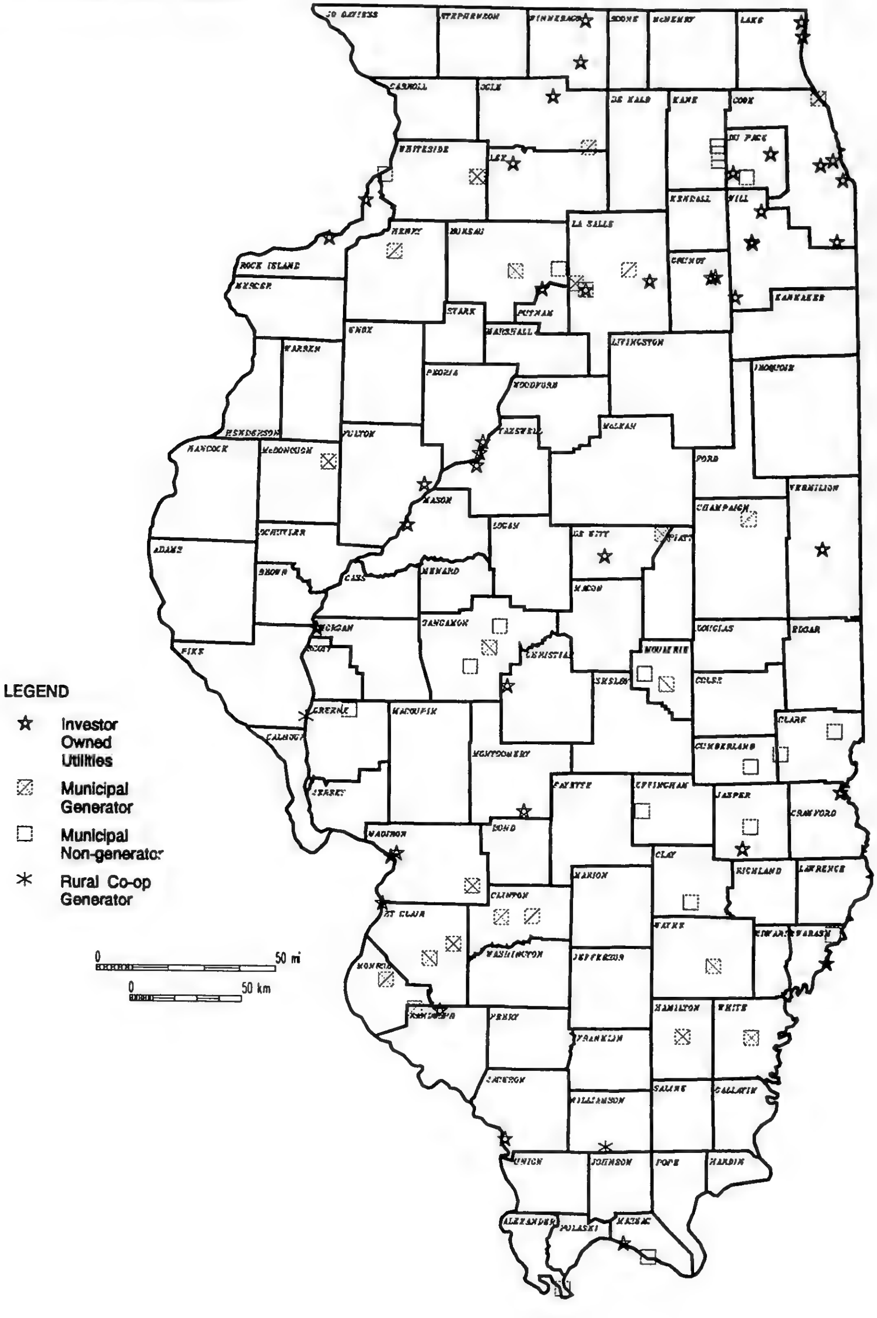
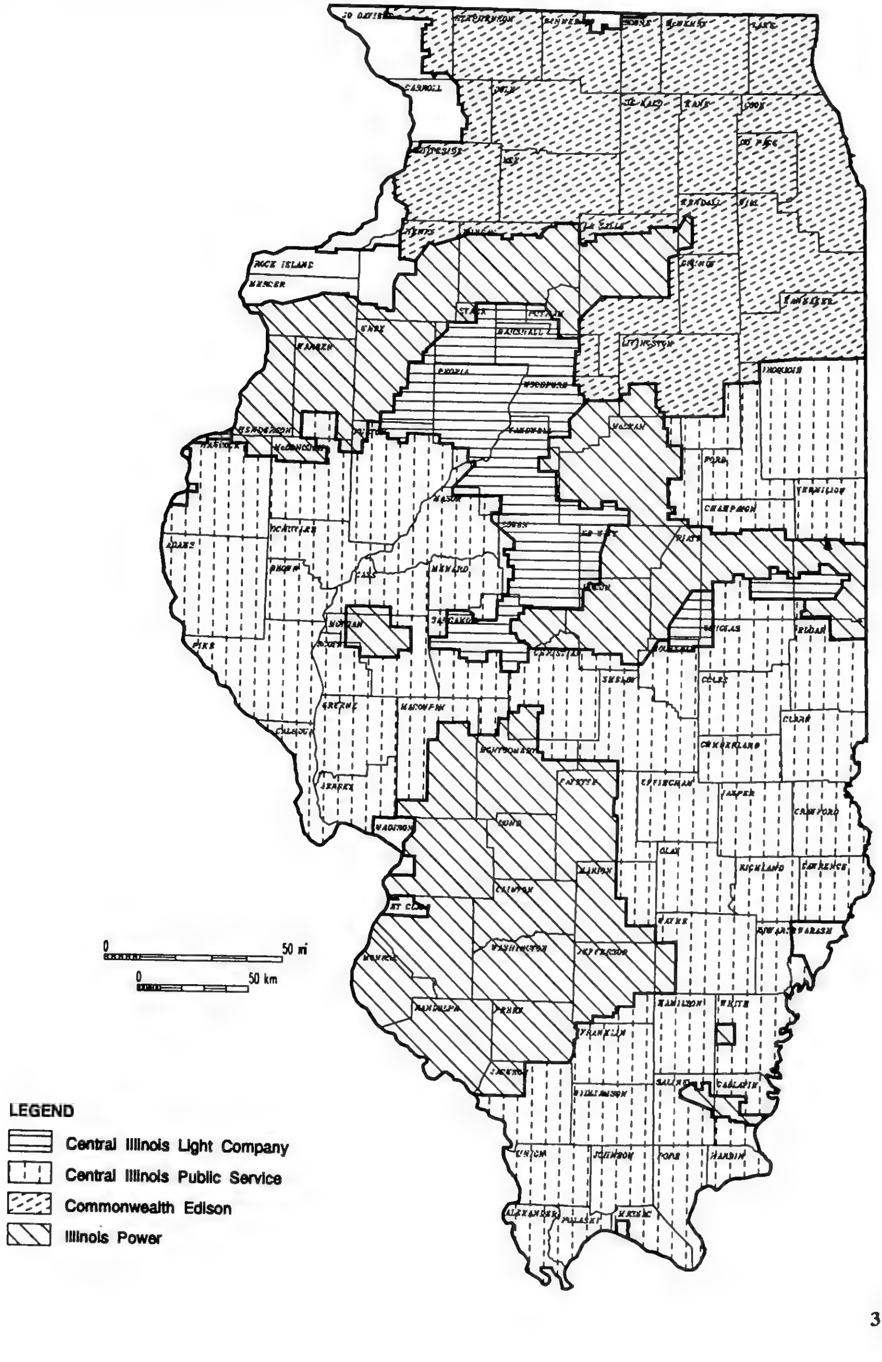


Figure 2. Major investor owned electric utility service areas.



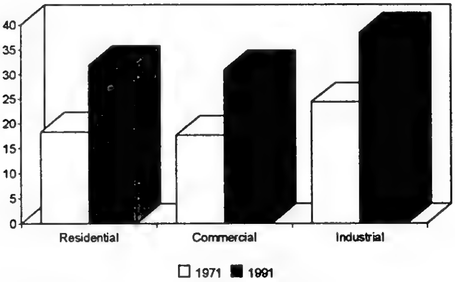


Figure 4. Consumption by customer class (billion kWh).

Industrial customers are manufacturing firms included in SIC codes 20 - 39, in addition to large users in the mining, transportation and sanitary SIC categories. Although industrial customers are fewer in number than the residential or commercial customers, they account for 40-50% of the electric consumption in the state. Therefore they have the highest consumption per customer ratio of all three classes.

Industrial electricity consumption grew at an annual compound rate of 3% per year from 1970 to 1991. Consumption remained fairly stable from 1986 to 1991 with increases averaging slightly less than 2% per year. In 1991, industrial consumption reached approximately 39 billion kilowatt-hours, a 64% increase over the 1970 level.

ELECTRICITY GENERATION

In 1973, Illinois utilities generated 92.516 million kilowatt-hours of electricity, with 78.2% generated from fossil fuels and 21.6% generated from nuclear fuel. Of the fossil fuel, 88% was coal, 7.58% oil, and 4.3% natural gas. By 1983 generation increased to approximately 99.043 million kWh, a 19% increase. The percent generated from fossil fuels decreased to 72% while the percent generated from nuclear fuel increased to 28%. From 1983 to 1989, generation increased 28% to 126.841 million kWh, for a 52% increase since 1973. The percent generated from nuclear power (59%) was now greater than the percent generated from fossil fuels (41%). (Edison Electric Institute, 1973, 1983, 1990-1991.)

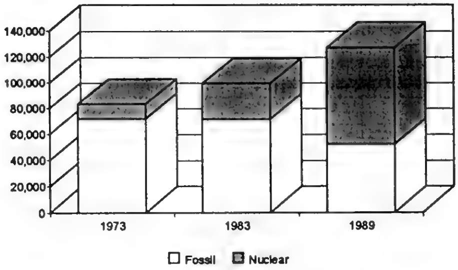


Figure 5. Statewide fossil and nuclear electric generation (gWh).

Electricity generation grew in Illinois at an annual compound rate of 1.8% annually between 1973 and 1983. However, the growth rate increased to an average 4.2% per year in the six years from 1983 to 1989, primarily the result of the country's overall economic recovery (Figure 5). The increased generation was supplied by nuclear fuel, which increased generation from 11,659 gigawatt-hours (gWh) in 1973 to 28,021 gWh in 1983 (up 14%), and to 74,820 gWh in 1989 (up 28.3%). Between 1973 and 1983, generation from fossil fuel remained unchanged at about 71,000 gWh and then declined to about 52,000 gWh by 1989. Coal experienced the most significant decrease.

EMISSIONS

Statewide levels of utility air emissions were calculated using AP-42 emission factors and fuel usage. Emissions data for Illinois utilities was obtained from Resource Data International (RDI). This section presents trends on the traditional major pollutants generated from fossil fuel plants and low-level radioactive waste generated at nuclear power plants. The fossil fuel pollutants are sulfur dioxide (SO_2), nitric oxides (NOx), particulates, and carbon monoxide (CO). (See *Volume 3* for additional data on energy resources and emissions.)

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[2] This ratio is the number of statewide megawatt-hours divided by the annual emissions of SO_2 in tons.

[3] This ratio is the number of emissions in tons divided by gigawatt-hours. The smaller the number the more electricity produced per ton of emissions.

Sulfur Dioxide

In 1973, statewide emissions of SO_2 were approximately 1.7 million tons per year; this number dropped 37% to 1.1 million tons per year by 1983. SO_2 emissions continued dropping and by 1989 the annual emissions were approximately one-half (870 thousand tons) of the 1973 levels (Figure 6). This decrease, coupled with the increase in electrical production, yielded an increase in the amount of electricity generated per ton of SO_2 emissions[2]. For example, in 1973 utilities produced 48 megawatt-hours (mWh) per ton of SO_2 emissions. By 1983 this had increased to 90 mWh per ton of emissions and continued to increase to 146 mWh per ton of SO_2 emissions by 1989.

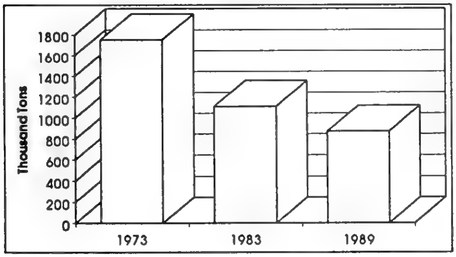

Figure 6. Statewide emissions of SO_2 from electricity production.

The decrease in SO_2 emissions was not solely attributable to the increase in nuclear generated power; the Clean Air Act also contributed to the reduction. For example, in 1973 there were approximately 24.4 tons of SO_2 emissions per gigawatt-hour produced from fossil fuels[3]. By 1983, the annual rate had declined to 15.6 tons of SO_2 per fossil gigawatt-hour. The rate increased slightly between 1983 and 1989 to 16.7 tons of SO_2 per fossil gigawatt-hour.

Nitrogen Oxides

Between 1973 and 1989 NOx emissions dropped almost 20%, from approximately 356 thousand tons to 289 thousand tons (Figure 7). The amount of megawatt-hours generated per ton of emission increased from 234 mWh per ton in 1973to 439 mWh per ton by 1989. However, the tons of emissions per fossil gigawatt-hour has not changed as significantly as it has for SO_2, moving only from 5 tons of NOx in 1973 to 5.6 tons by 1989.

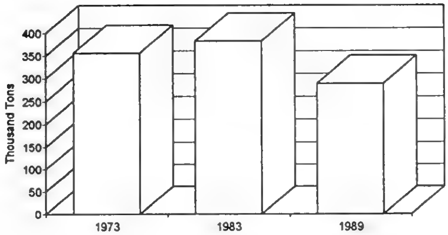

Figure 7. Statewide emissions of NOx from electricity production.

Particulates

Particulate emissions have decreased 81%, from roughly 96,000 tons to 18,000 tons per year (Figure 8). The megawatt-hours per ton of emissions increased from 863 hours in 1973, to 2,438 hours in 1983 and 7,012 hours by 1989. As with the SO_2 reduction, the decrease in particulates cannot be solely attributed to the increase in nuclear production; the ratio of tons of emissions per fossil gigawatt-hour decreased from 1.3 tons in 1973 to .6 tons in 1983 and dropped even further to .3 tons by 1989.

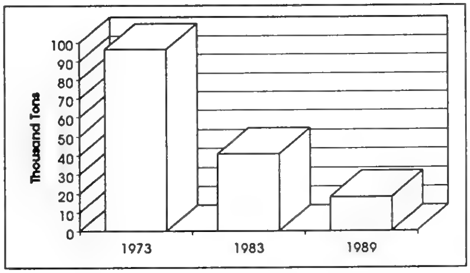

Figure 8. Statewide particulate emissions from electricity production.

Carbon Monoxide

Reductions in CO emissions have been steady but not as dramatic as for particulates. Total annual CO emissions in 1973 were estimated at 17 thousand tons, at 15 thousand tons in 1983 and 11 thousand tons in 1989, a 35% reduction in the 16-year period (Figure 9). The tons of emissions per fossil fuel gigawatt-hour decreased only slightly, from .24 tons in 1973 to .22 tons in both 1983 and 1989.

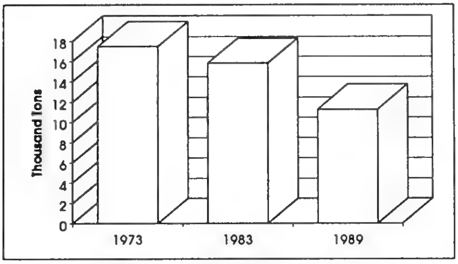

Figure 9. Statewide CO emissions from electricity production.

Figure 10 illustrates the tons of emissions, for all four pollutants, per gigawatt-hour of electricity generated (from both fossil and non-fossil fuel).

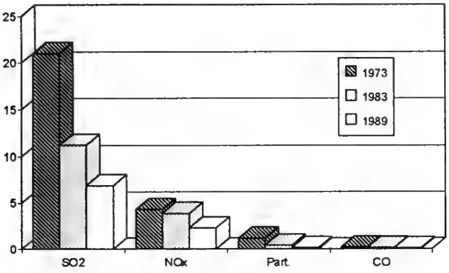

Figure 10. Tons of emissions per gigawatt-hour of electricity.

Low-Level Nuclear Waste

Illinois is the largest producer of nuclear power in the United States, operating seven nuclear power stations. Although air emissions data on radioactive emissions were unavailable, low-level nuclear waste data was available from the Illinois Department of Nuclear Safety.

Because the volume of waste shipped varies widely on an annual basis, both the annual total and a five-year average are shown in Figure 11. Based on the five-year average, the volume of waste shipped in 1974 was 94 thousand cubic feet; it peaked in 1978 at 243 thousand cubic feet and by 1991 it had dropped back to 110 thousand cubic feet. While the volume of waste declined between 1976 and 1991, nuclear generation increased substantially, by 144%. The decline in volume could be due to improvement in treatment processes or changes in production processes (IDNS, 1991). The major peaks in 1976 and 1978, for both the annual and the five-year averages, were due to large volumes from one facility.

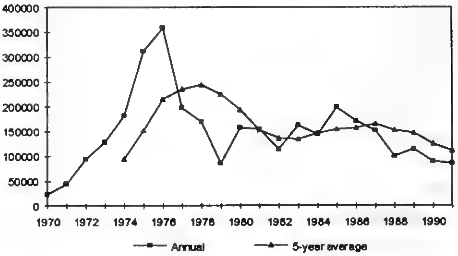

Figure 11. Cubic feet of low level radioactive waste shipped by Illinois utilities.

At the same time that volume was decreasing, the reported radioactivity (in curies) of low-level waste was increasing (Figure 12). Using the five-year average, in 1974 the average level of radioactivity was 426 curies, in 1983 the average was more than 10 thousand curies, and in 1991 it was 41 thousand curies. Subsequently, the ratio of megawatt-hours per curie of low level waste decreased from 9.39 thousand mWh in 1983 to 2.69 thousand mWh by 1989. The spike in radioactivity in 1989 was caused by several shipments of activated hardware, consisting of about 400 cubic feet and more than 130,00 curies, from two reactors belonging to one utility. Some of the activated hardware had been in storage for more than 10 years. Clean-out of such waste usually requires special handling and is very expensive.

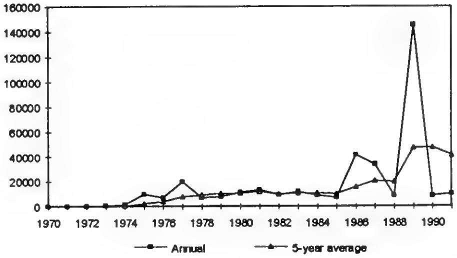

Figure 12. Radioactivity (curies) of low-level waste shipped by Illinois utilities.

Although low-level wastes are currently disposed of in South Carolina (the contract is scheduled to terminate on June 30, 1994), Illinois has a compact with Kentucky to build a disposal site in Illinois for the use of both states.

ILLINOIS MAJOR UTILITIES

In 1991, 88 electric utilities — investor-owned, municipal, and rural cooperatives — operated in Illinois. The largest are the seven private investor-owned utilities which serve more than 90% of all electric customers and have a combined net capability of 34,114,463 kilowatt-hours. They are regulated by the Illinois Commerce Commission to ensure that pricing and service policies are managed in the public interest. Trends for three of the investor-owned utilities — Commonwealth Edison, Illinois Power, and Central Illinois Light Company — are presented in the following sections.

Commonwealth Edison Company

Commonwealth Edison, headquartered in Chicago, is the largest utility in Illinois and has the largest generating capacity, energy sales, number of customers, and assets. The company operates 21 generating plants, six of which are nuclear facilities. With a maximum name plate generating capacity of more than 24 thousand megawatts in 1991, the company produces more electricity than all other investor - owned utilities combined. Its net generation in 1991 was approximately 102 million kWh. Through its seven major interconnections, 5,000 circular miles of transmission facilities, and 65,000 pole miles of distribution lines, the company delivers electricity to 3.2 million customers. Edison's total electric sales grew from 46,062,276 megawatt-hours in 1970 to 78,601,111 megawatt-hours in 1991, a 70% increase.

Coal consumption by Commonwealth Edison's fossil fuel facilities grew in the early 1970's (to around 19 million tons) but by 1975 began dropping until use jumped again in the early 1980's (Figure 13). The increase was shortlived, however, because nuclear generation was growing at the same time and by 1992 Edison's coal usage declined significantly to 7.4 million tons, a 55.3% decline from 1970.

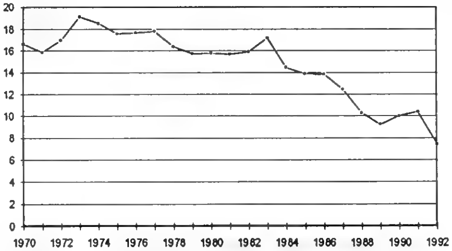

Figure 13. Annual coal usage by Commonwealth Edison (million tons).

Fossil Fuel Emissions. Between 1970 and 1990, SO_2 emissions dropped 85% (at an annual compound rate of slightly over 4%), NOx declined 43.5%, CO 55.2%, CO_2 41.8%, VOCs 57% and total suspended particulates (TSP) 97.8%. The reduction can be attributed to the Clean Air Act and the growth in nuclear power. Air emission trends are presented in Figures 14-17.

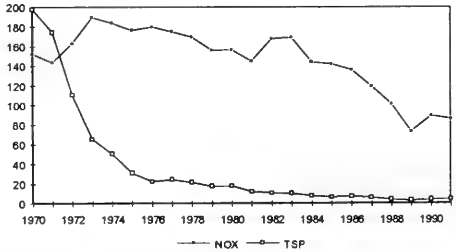

Figure 14. Emissions of NOx & TSP (thousand tons) from Commonwealth Edison's fossil fuel facilities.

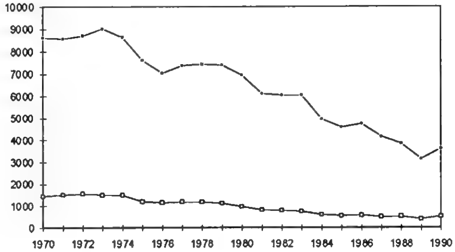

Figure 15. Emissions of CO & VOCs (tons) from Commonwealth Edison's fossil fuel faciities.

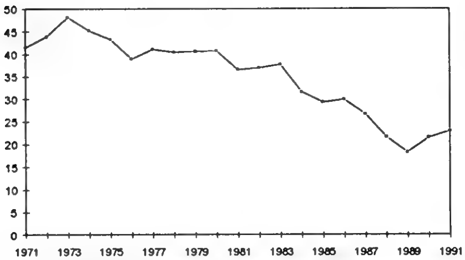

Figure 16. CO2 emissions (million tons) from Commonwealth Edison's fossil fuel facilities.

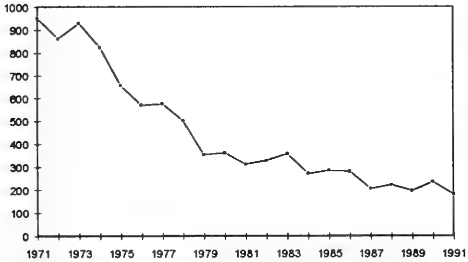

Figure 17. SO2 emissions (thousand tons) from Commonwealth Edison's fossil fuel facilities.

Total Ash. Coal combustion produces ash as a by-product — bottom ash is collected at the bottom of the boiler, and fly ash is collected within the stack by electrostatic precipitators. In 1980, Commonwealth Edison generated 923 thousand tons of ash (61.5% fly ash, 38.5% bottom ash); this number dropped 6% by 1990 when the company generated 864 thousand tons of ash (49% fly ash, 51% bottom ash). The amount of fly ash generated declined 25% over the 20 years while bottom ash increased 48.7% (Figure 18). The decrease in fly ash is somewhat due to the switch to low-sulphur coal and an overall reduction in coal usage.

Ash is either buried in landfills dedicated to ash disposal or used in other products, such as highway and building construction concrete; roofing; road de-icer; granule, sewer and drainage line backfill materials; and as foundation material for grading building sites and road rights-of-way. In 1991, approximately 33% of the total ash was landfilled. (Commonweath Edison, 1992).

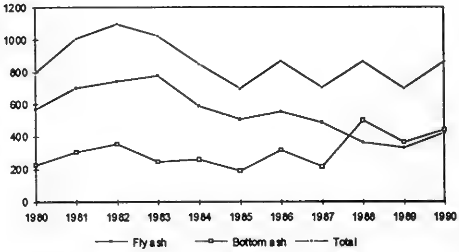

Figure 18. Ash waste (thousand tons) from Commonwealth Edison fossil fuel plants.

Nuclear Power. Commonwealth Edison is the largest producer of nuclear power in the United States, operating six nuclear generating facilities (ICC, 1989). Nuclear power production in 1979 was approximately 25 million kWh; in 1989 it was approximately 69 million kWh (Figure 19).

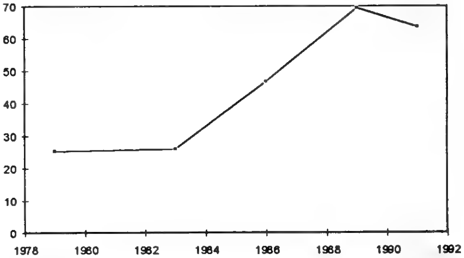

Figure 19. Commonwealth Edison nuclear power generation (million kWh).

Prior to 1987, before Illinois Power's Clinton Nuclear Plant came on line, most low-level nuclear waste generated in Illinois came from Commonwealth Edison facilities. For the most part, the statewide trends in nuclear waste presented in Figures 11 and 12 mirror Commonwealth Edison's trends — volume has steadily decreased while activity in terms of curies has steadily increased. The high-level nuclear waste generated is currently stored on-site, but a federal mandate requires the U.S. Department of Energy to dispose of the high level waste by 1998 (Commonwealth Edison, 1992).

Illinois Power

Illinois Power (IP) provides electricity to 124 communities with approximately 560,000 customers. With its corporate office in Decatur, IP operates seven fossil fuel plants and one nuclear facility, accounting for a total generating capacity of roughly 4.2 million kWh. With as many as eight interconnections, the utility delivers electricity through 2,800 circular miles of transmission lines and 20,000 prim pole miles of distribution facilities. IP is Illinois' second largest electric utility and consumes significant amounts of fossil fuel.

Coal consumption at IP increased at an annual compound rate of slightly over 3% per year from 1970 to 1991. In 1970, IP consumed 3.8 million tons of coal and 18,000 barrels of oil. In 1973, consumption was up to 5.2 million tons of coal and 1.3 million barrels of oil, an increase of 37% and 71% respectively. For the next ten years coal usage increased steadily, reaching 7.4 million tons, while oil usage plunged to 217 thousand barrels, a decline of nearly 89%. Between 1983 and 1986, coal usage increased 4%, reaching 7.7 million tons, while oil usage declined to 183,000 barrels. Since then, coal consumption has dropped to 6.3 million tons in 1991. The decline in coal consumption between 1986 and 1991 can be attributed to the commissioning of the Clinton nuclear facility in 1987 (Figure 20).

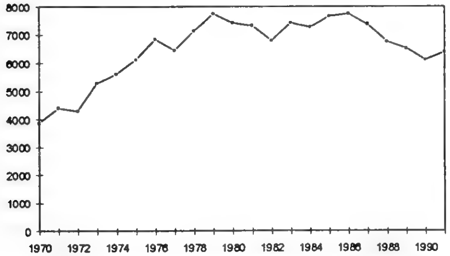

Figure 20. Illinois Power coal consumption (thousand tons).

Fossil Fuel Emissions. Fossil fuel emissions of SO_2, NOx, and CO have all declined since the early 1980's (Figures 21-23). SO_2 emissions from all Illinois Power's fossil fuel sources were 243,000 tons in 1970; emissions peaked in 1979 at 385,000 tons. In 1991, emissions were down to 229,000, a 5.5% decline from 1970 emissions.

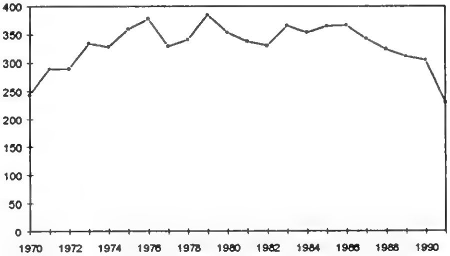

Figure 21. Illinois Power SO2 emissions (thousand tons).

NOx emissions were 40,000 tons in 1970 and 90,000 tons in 1978, an increase of 123.4% in just eight years. Over the next five years emissions went up another 3%, reaching 93,000 tons. The decline began in the mid-1980's, with NOx emissions dropping to 85,000 tons in 1985 and 81,000 tons in 1991, still more than double the amount emitted in 1970.

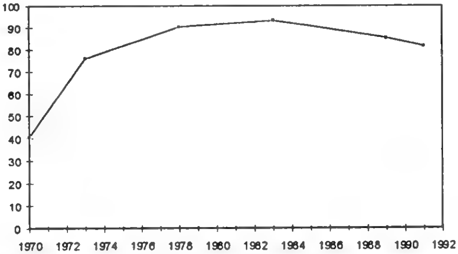

Figure 22. Illinois Power NOx emissions (thousand tons).

CO emissions in 1970 stood at 1,417 tons; in 1978 they had increased 677%, to 11,000 tons. Since then, CO emissions have taken a downward trend — to 10,000 tons in 1983, 9,000 in 1989, and 2,000 in 1991. Despite the downward trend, 1991 CO emissions reflected a 42% increase over 1970 emissions.

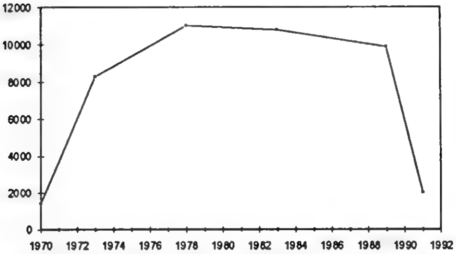

Figure 23. Illinois Power CO emissions (tons).

Total Ash. Trends in ash disposal (Figure 24) correspond with the company's coal usage during the same period. In 1976, Illinois Power disposed of 746,000 tons of ash; in 1979, disposal increased 10.3% to 823,800 tons. The level of ash disposal fluctuated over the next twelve years, with an overall decline of 3% between 1976 and 1991, when 743,500 tons were disposed.

Using data submitted by IP to the Federal Energy Regulatory Commission, trends were developed for both fly ash and bottom ash. In 1976, fly ash and bottom ash disposal was 369,500 and 377,000 tons respectively. In 1991, fly ash disposal was 231,000 tons, a 37% decrease. Bottom ash, on the other hand, increased to 512,000 tons, a 35.8% increase.

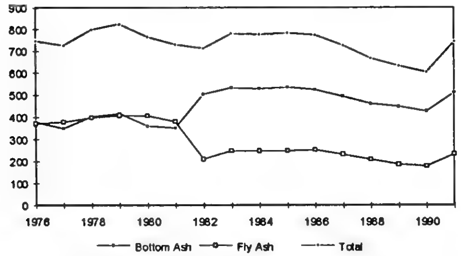

Figure 24. Ash waste (thousand tons) from Illinois Power coal facilities.

Nuclear Power. When the Clinton nuclear plant came on-line in 1987, IP became the second utility in Illinois with nuclear generating capacity. Because the facility is relatively new, sufficient data was not available to develop trends in low-level radioactive waste.

Central Illinois Light Company

Central Illinois Light Company (CILCO), headquartered in Peoria, is Illinois' fourth largest electric utility, serving 186,000 customers. Its service territories extend approximately 4,500 square miles through 150 communities in central and east central Illinois. CILCO's three plants in Peoria and Fulton counties have a total name plate rating of 1.257 million kWh. With five major interconnections, the company sends its electricity through 330.89 circular miles of high voltage transmission lines.

Unlike Commonwealth Edison and Illinois Power, CILCO has no nuclear power plants; it relies wholly on fossil fuel for electricity generation. Between 1970 and 1990, its coal usage increased at an annual compound rate of 1.3%, from 1.7 million tons a year to 2.2 million tons per year (Figure 25).

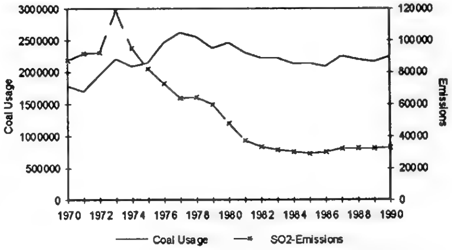

Figure 25. CILCO coal usage and SO2 emissions (both in tons).

Fossil fuel emissions. CILCO's SO_2 emissions declined from 87,000 tons in 1970 to 33,000 tons in 1990, primarily because the company installed emission controls at its new facility and switched to lower sulfur coal at all other facilities. The ratio of SO_2 emissions to total coal usage dropped significantly, from 4.91% in 1970 to a mere 1.48% in 1990. Data on the other air pollutants were not available for this analysis.

SUMMARY

In 1960, Illinois utilities produced more than 42 billion kWh of electricity, 90% of which were generated using coal, 9.1% using natural gas, and 0.04% using petroleum. By 1970, coal provided 77% of the statewide fuel mix, natural gas provided 16%, petroleum 3.5% and nuclear 3.4%. By 1990, total utility generation was 126.9 billion kWh. Of the total, 42.4% was generated from coal, 0.3% from fuel oil, 0.7% from gas and 56.6% from nuclear. Between 1960 and 1990 total generation grew 200%; however most of the growth was accomodated by nuclear power.

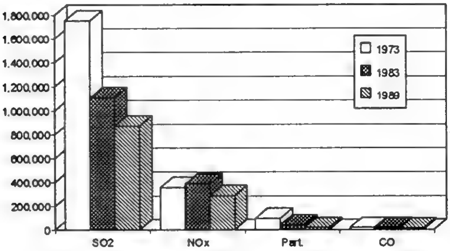

Figure 26. Electric utility emissions (tons/year).

Statewide emissions from all utility fossil fuels have declined substantially over the past twenty years. SO_2 declined 40%, NOx 19%, particulates 81%, and CO 36%. On the other hand, the level of radioactivity from low-level nuclear wastes (using the five-year average) increased from 10.5 thousand curies in 1983 to approximately 41 thousand curies in 1991, even while the volume of wastes declined.

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URBAN DYNAMICS

The CTAP source category 'urban dynamics' includes urban and built-up lands and the populace which lives and works there, and the urban economic system — the flow of money, goods and services, and materials. For this study, the urban economic sector includes construction (SIC 15-17); wholesale trade (SIC 50-51); retail trade (SIC 52-59); finance, insurance and real estate (SIC 60-67); services (SIC 70-89); and government (SIC 91-97).

ECONOMIC TRENDS

Statewide

Over the 20-year period from 1971-1991, the economic output (using constant 1987 dollars) of six of these sectors increased while construction decreased 19%. The greatest increase was in the services sector, with an 87% increase. Retail trade increased 55%, wholesale trade, 54%, finance, insurance and real estate, 28% and government, 12%. (Illinois Economic Summary, First Quarter, 1993.)

From 1967-1990, statewide employment in these sectors grew considerably (see Figure 1). Services grew 224%; finance, insurance and real estate grew 138%, construction, 91%, retail trade, 68%, wholesale trade, 42%, and government, 14%. (County Business Patterns, Office of the State Comptroller)

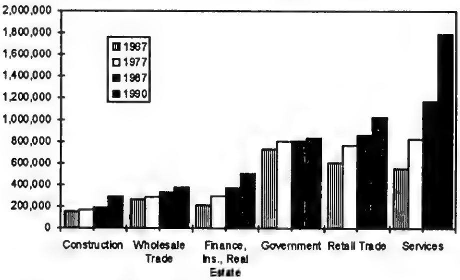

Figure 1. Number of employees per sector.

In the following sections, employment trends for the period 1967 -1989 are discussed for Cook County, DuPage County, other Metropolitan Statistical Area's (MSA's), and the balance of the state. DuPage County was treated separately because it is the fastest growing county in the state; Cook County because it is the largest.

Construction Employment

Over the 22-year period, construction employment increased in DuPage County by 444%; in other MSA's by 47%; and in Cook County, 11%. Areas outside of MSA's (rest of state) suffered an 11% decline in construction jobs during the same time period.

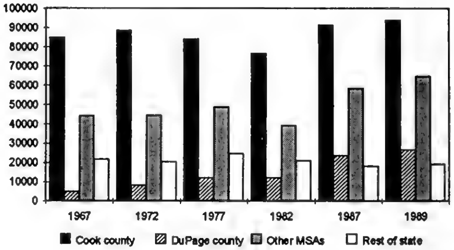

Figure 2. Number of construction employees by geographic area.

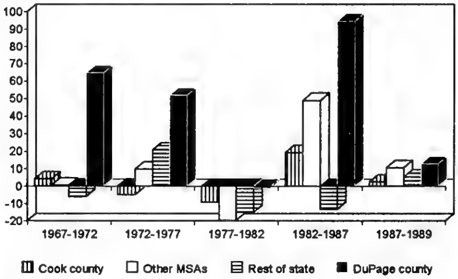

Figure 3. Percent change in construction employment.

Common to all areas was a decline in construction jobs between 1977 and 1982. The next five-year period, however, brought the greatest increase in construction jobs for DuPage County, the other MSA's, and Cook County, the areas which saw overall employment increases. The rest of the state had its largest increase between 1972 and 1977.

Wholesale Trade Employment

During the 22-year period wholesale trade employment grew in each of the geographic divisions except Cook County. Cook County's figures were relatively steady except for the drop between 1972 and 1977, the same time period when DuPage County, the other MSA's and the rest of the state had their largest increases. Unlike DuPage County and other MSA's, however, the rest of the state suffered a decline during the following five-year period.

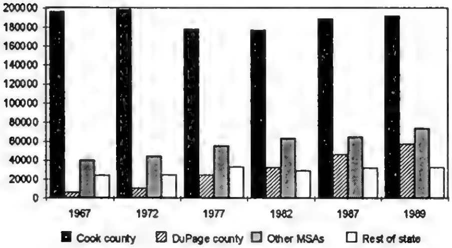

Figure 4. Number of wholesale trade employees.

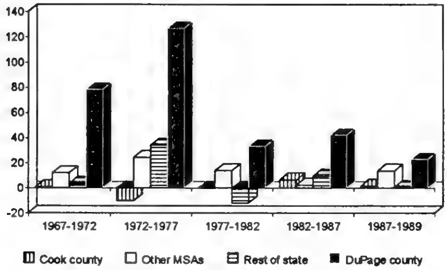

Figure 5. Percent change in wholesale trade employment.

Retail Trade Employment

Retail trade experienced increasing employment in each geographic area during the 22-year period. DuPage County led with a 336% increase, followed by other MSA's with 85%, the rest of the state with 32%, and Cook County with 21%.

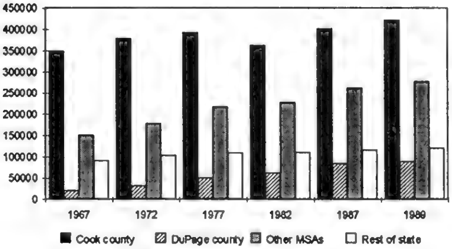

Figure 6. Number of retail trade employees.

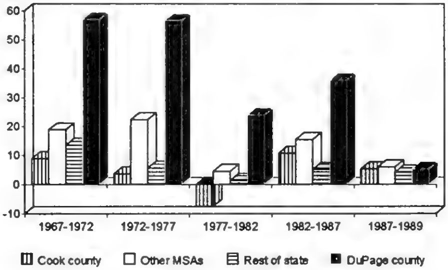

Figure 7. Percent change in retail employment.

The only decrease in employment occurred in Cook County, which suffered an 8% drop between 1977 and 1982. This five-year period was also the slowest growth period for other MSA's and the rest of the state. The rates of growth for DuPage County and the rest of the state reached their highest levels in the first five-year period, followed by two periods of declining growth, and then an alternating increase and decline in employment growth. Other MSA's reached their highest rate of growth between 1972 and 1977. Surprisingly, by 1987 and 1989 employment growth tapered off to approximately the same rates in each area.

Finance, Insurance and Real Estate Employment

This sector also grew in each geographic area. The largest growth occurred in DuPage County,which had an 809% increase over 22 years. Growth in other MSAs, the rest of state, and Cook County was 122%, 61%, and 60% respectively.

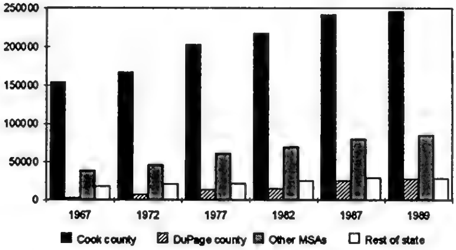

Figure 8. Number of employees in finance, insurance and real estate.

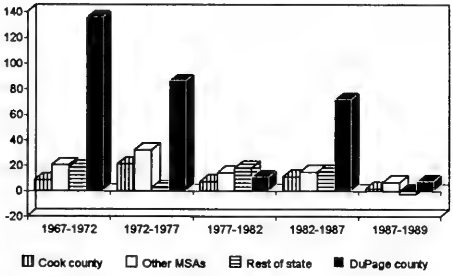

Figure 9. Percent change in finance, insurance and real estate employment.

The slowest rates of employment growth occurred between 1987 and 1989, the period during which the balance of the state experienced a 3% decline in employment. Cook County and other MSA's had their highest rates of employment growth between 1972 and 1977, with growth tapering off by 1989. In DuPage County and the rest of the state, the greatest employment growth occurred during the first five-year period. DuPage County's employment growth decreased during the next ten years before rebounding during the 1982-1987 period.

Service Employment

Service employment rose steadily in all areas during each five-year period. Overall, DuPage County service employment grew 539%, followed by other MSA's, 180%; the rest of the state, 119%; and Cook County, 102%.

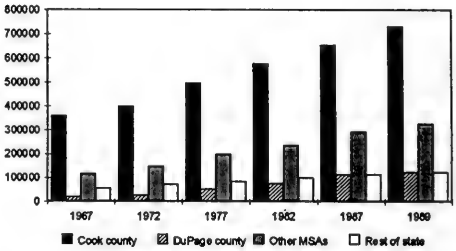

Figure 10. Number of service employees.

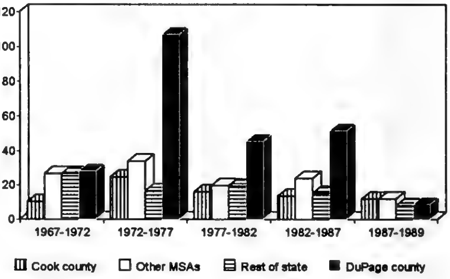

Figure 11. Percent change in service employment.

In Cook County, DuPage County, and the other MSA's the greatest change in employment came during 1972 to 1977. Employment growth in these areas declined but remained steady in the following two periods before dropping to a considerably lower level in the 1987 to 1989 period. Employment change in the rest of the state grew most between 1967 and 1972, and declined slightly during the following periods.

POPULATION TRENDS

One Hundred Year Trends

Illinois population trends were analyzed for Cook County, collar counties, downstate MSA's[1] and non-MSA's (rural counties) from 1890 to 1990. Figure 12 shows the 100-year growth rates for these areas, Figure 13 shows their growth rates by decade, and Figure 14 shows the 100-year growth rate of downstate MSAs.

During the 100-year period, statewide population grew 200%, from 3,773,475 to 11,430,602 persons. With the exception of a mere 5% population increase in the 1940 census, growth from the turn of the century was relatively steady at about 10-17% until 1970. After 1970, growth declined significantly to 0 - 3%.

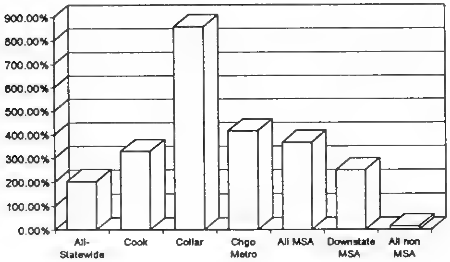

Figure 12. One hundred year population growth rates, 1890 - 1990.

Rural Counties

Since the turn of the century, rural Illinois has grown about 14% in population, with most of that increase occurring between 1890 and 1910. Not much growth has taken place since then. A slight increase occurred between 1970 and 1980, but an equivalent decrease occurred between 1980 and 1990. Only five counties in this category showed any population increase between 1980 and 1990, with DeKalb registering the most, a 3,300 person increase. The population density has remained relatively steady, ranging from 43 to 51 persons per square mile over the 100-year period.

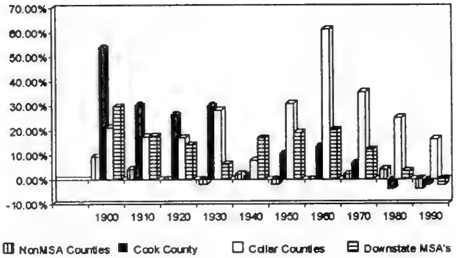

Figure 13. Population growth rates by decade, 1890-1990.

Cook County

Cook County has been, since before the turn of the century, the most highly urbanized county of the state, with population densities ranging from 1,250 persons per square mile in 1890 to 5,354 in 1990, 20 to 30 times higher than the statewide average. Cook County's ten-year growth rates range from nearly 60% at the turn of the century, to 30% during the early part of the century, to nearly 0% in recent years. The data indicate that Cook County growth parallels that of the downstate "MSA" counties albeit at a 15-20% higher rate, until 1940 when the downstate MSA rate began to exceed the Cook County rate by about 5% to 8%. Both areas experienced declines of 2-3% in 1990. The 100-year Cook County growth rate is about 328%.

Collar Counties

The Illinois counties of DuPage, Grundy, Kane, Kendall, Lake, McHenry, and Will are included in the "collar county" category. The aggregate population density of this category has increased tenfold to about 630 persons per square mile in 1990. Growth rates were fairly steady, in the 20-30% range, until a drop-off to about 8% in 1940 and a subsequent return to 16 - 60% growth. The highest growth occurred in the

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[1] The aggregation of counties into Metropolitan Statistical Areas (MSAs) is based on the 1992 Illinois Statistical Abstract. It should be noted that classification has changed since MSA's were first defined in the 1950 census. In 1972, Clinton and Monroe counties became part of the St. Louis MSA and Menard County became part of the Springfield MSA. In 1987, Kendall County joined the Chicago Consolidated MSA. A MSA is a county or group of contiguous counties that contain at least one city of 50,000 inhabitants or more, or twin cities with a population of at least 50,000. In addition to the county, or counties, containing such a city or cities, contiguous counties are included in a MSA if, according to certain criteria, they are socially and economically integrated with the central city. The MSA is identified by the central city or cities, i.e. Bloomington MSA.

1950's, with the 1960 census showing a 61% population increase, the highest single growth in any category, approached only by Cook County's growth rate of 54% at the turn of the century. Collar County growth rates dominate the comparative presentation of growth rates for the last half of the century (Figure 13). The 100-year Collar County aggregate growth rate is about 860%.

Chicago Metro Counties

The Chicago Metro County category includes all "Collar Counties" and Cook County. The aggregate density of these counties was 1,639 persons per square mile in 1990. This density is about one-fourth the density of Cook County taken alone and about 2.5 times the density of the collar counties, without Cook. The growth rates for the Chicago Metro counties are modulated by comparison to the collar and Cook rates taken independently. The 100-year Chicago Metro aggregate growth rate is about 415%.

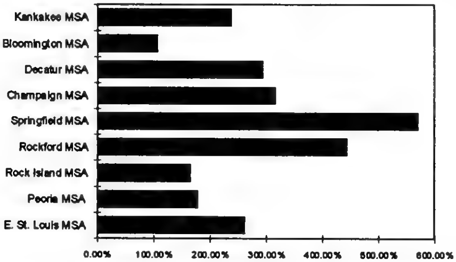


Figure 14. One hundred year growth rates, 1890-1990, downstate MSA's.

Downstate "MSA's"

This category is composed of 18 counties within the downstate "MSA's" of East Saint Louis, Rock Island, Peoria, Rockford, Bloomington, Decatur, Champaign, Kankakee and Springfield (Figure 14). Population densities in this group have increased from 54 persons per square mile at the turn of the century to 190 in 1990. Growth rates are shown to be fairly steady in the 20-30% range until a drop-off to about 8% in 1940 and a subsequent return to a growth rate of about 20% in 1960. After 1960 there was a decline to marginal negative growth in 1990. The 100-year Downstate "MSA" county growth rate is about 250%.

Recent Trends

Figure 15 shows trends in the distribution of the state's population among Cook County, the Chicago collar counties, other urban counties (MSA's), and the rest of the state over the past 30 years. Most noticeable is the decrease in the percentage of Illinois' population residing in Cook County. In 1960, 51% of the state's population lived in Cook County, but this number had fallen to 45% by 1990. The collar counties doubled their percentage, rising from 11% to about 20% by 1990 and downstate MSA's have gone from 27% of the population living in these areas in 1960 to 31% in 1990. The rest of the state, like Cook County, is contributing a smaller percentage to Illinois' population, 17% as compared to 19% in 1960.

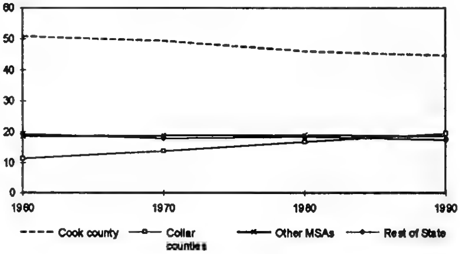
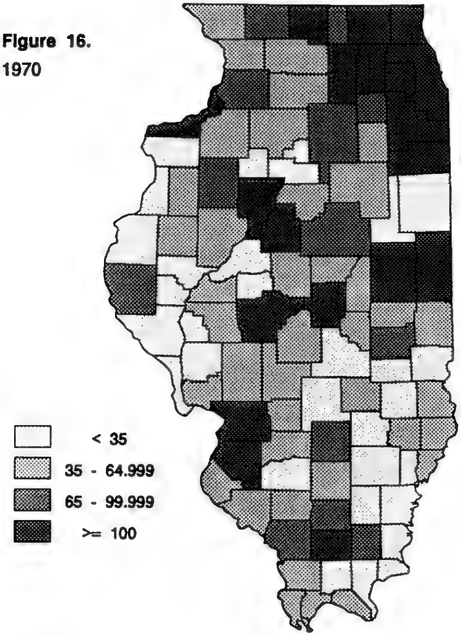


Figure 15. Population distribution (percentage of total), MSAs and rural, 1960-1990.

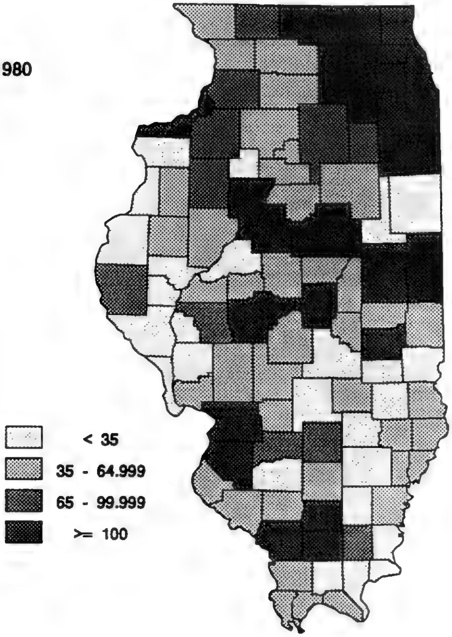
Using numbers from the 1980 and 1990 census, Figure 16 shows changes in county population density and Figure 17 graphically illustrates the percent change in population for each county. The greatest population losses occurred in the western and central counties of Henry, Stark, Marshall, Henderson, Warren, Fulton, Mason and Cass. Population gains occurred in McLean County (central Illinois), Brown County (western Illinois), Monroe County (Metro-East area), and Johnson County (southern Illinois). Two other southern counties, Alexander and Pulaski, experienced significant population declines.

Figure 16.

1970



1980



1990

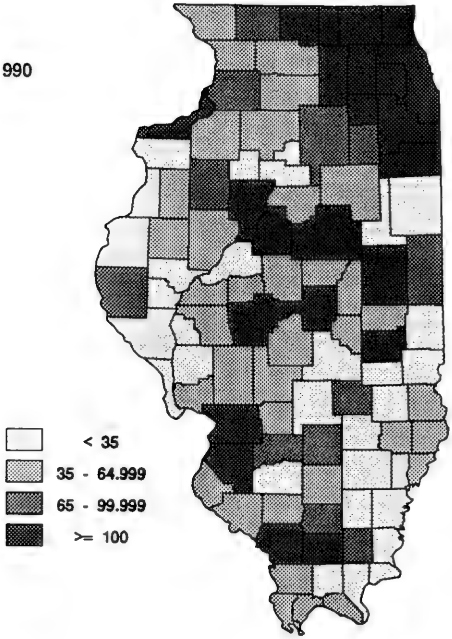
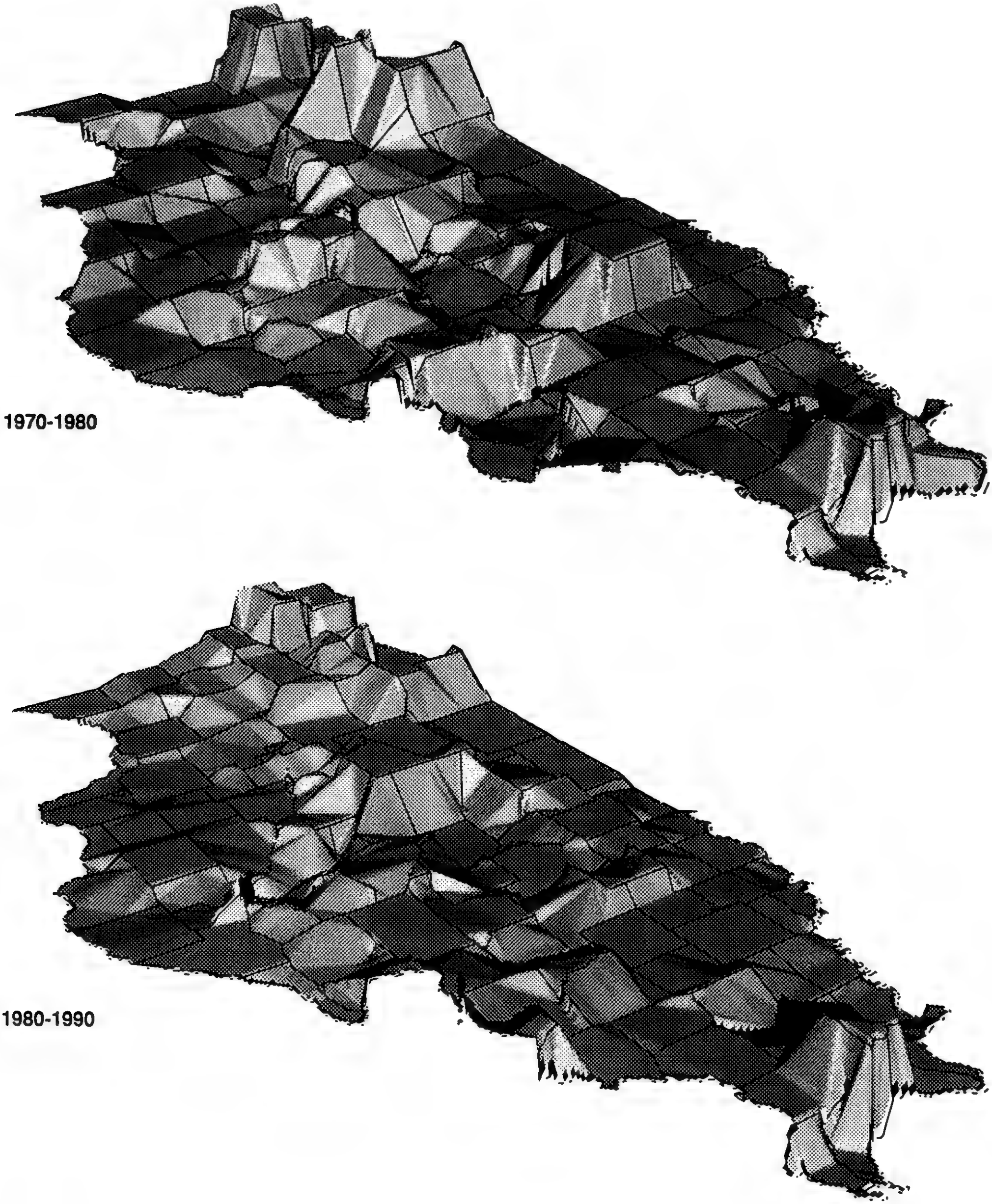


Figure 16. COUNTY DENSITY 1970 - 1990.
Counties are classified based on their population per square mile.
Source: U.S. Census Bureau, 1970, 1980, 1990.

Figure 17. Percentage change in population by county.



1970-1980

1980-1990

Population Distribution

In the mid-nineteenth century, Illinois was overwhelmingly a rural state. The 1840 census reports that only 2% of the population lived in urban areas. By the 1860 census, however, that figure had jumped to 14% of the population living in 23 urban centers. Chicago was by then the major city in Illinois and quickly becoming industrialized. Peoria, the second largest city, was becoming known as a manufacturing center and saw its population jump 176% during the 1850s. At the same time, trade centers were springing up where railroads crossed, as in Mendota, Galesburg, Decatur and Matoon, and Illinois Central (railroad) stations provided the nexus for other towns, such as Effingham, Harvey, Homewood, Normal and Pana. (Howard 1972)

Over the next one hundred years (see Figure 18), the population continued to shift from rural to urban (greater than 2,500 population) and by 1990 the urban population was 85% compared to 15% rural. (Clayton, 1970 and 1990 Census)

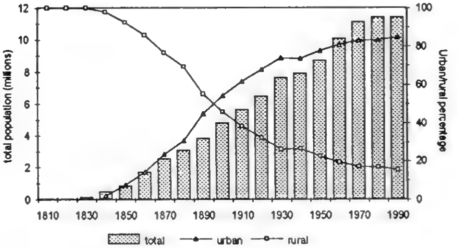


Figure 18. Illinois population, 1810-1990.

One hundred years after urbanization began a new trend took hold in Illinois as people began moving to the urban fringe, the closely settled areas surrounding central cities. By 1990 as many people lived on the urban fringe as lived in central cities. [2] Figure 19 shows the percentage of Illinois' population residing within the central cities, urban fringe, other urban areas, and rural areas. Not only are fewer people living in rural areas, central cities, and other urban areas, but these areas are contributing a significantly smaller percentage of the total state population.

Rural areas accounted for 19% of the state's population in 1960, but declined to 15% in 1990. During the same three decades, central city population fell from 42% of the state total to 37%. In other urban areas, the percentage fell from 14% to 10% over the same 30 years. The only increase occurred in urban fringe areas, which rose from 25% of the state's population in 1960 and to 37% in 1990.

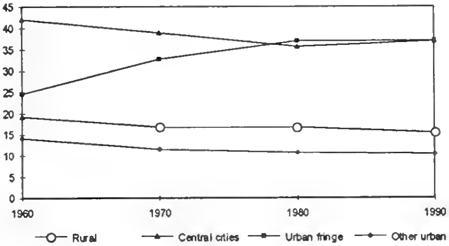


Figure 19. Population distribution (percentage of total) in urban areas, 1960-1990.

LAND USE TRENDS

The Northeastern Illinois Planning Commission (NIPC) has estimated that between 1970 and 1990 the population of the six-county region of Cook, DuPage, Lake, Kane, McHenry and Will grew 4%, while the number of households grew 20% and residential, commercial and industrial land grew by 51%.[3] In 1970, these three categories accounted for 45% of the area's developed land — the estimate does not include land used for streets, public open space, transportation, communications, utilities, and mining. By looking at the Census of Agriculture data on the

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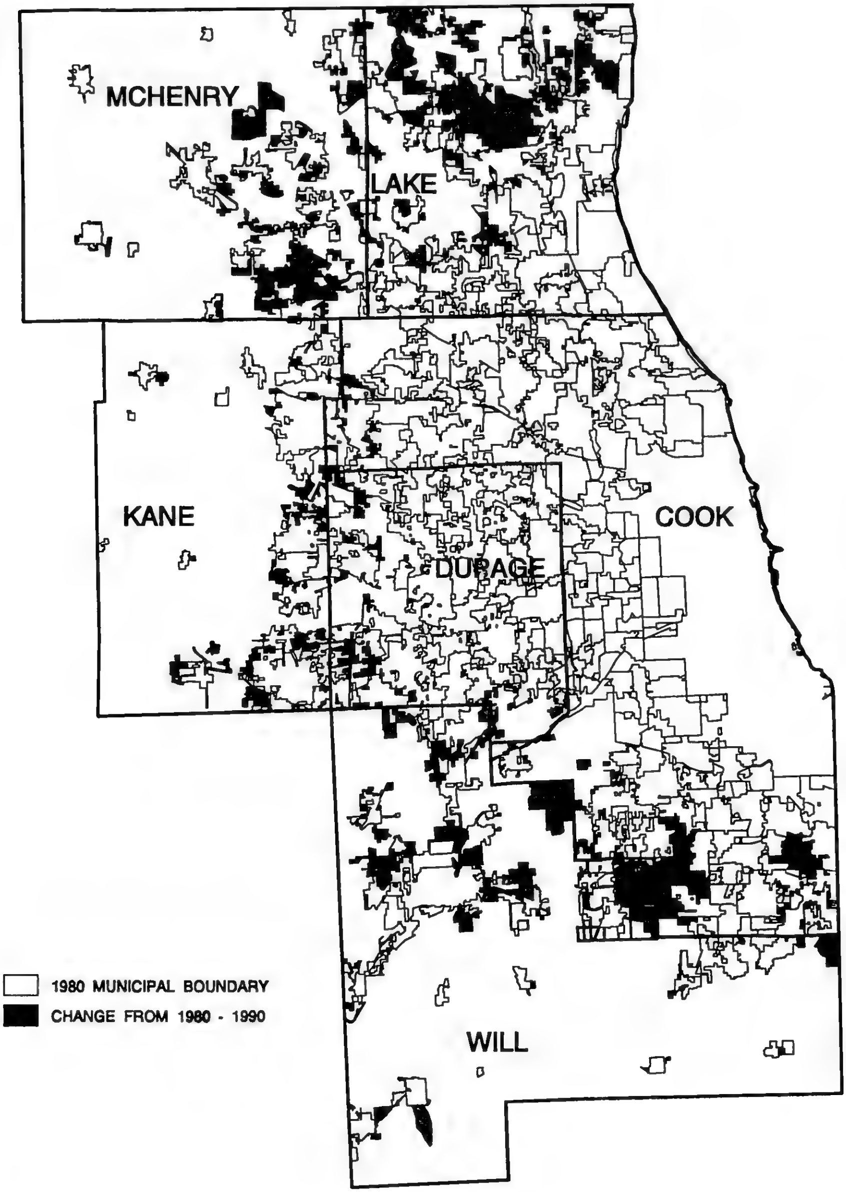
[2] According to the Bureau of the Census, to be a "central city" with an "urban fringe" (surrounding densely settled area), the combined population of the city plus fringe (urbanized area) must be a minimum of 50,000. Urbanized areas in Illinois include Alton, Aurora, , Bloomington-Normal, Champaign-Urbana, Chicago, Crystal Lake, Decatur, Elgin, Joliet, Kankakee, Peoria, Rockford, Rock Island-Moline, and Springfield. Urbanized areas located partially in Illinois include Beloit, WI; Dubuque, IA; Round Lake Beach, WI; and St. Louis, MO. "Other urban" areas are areas with at least 2,500 population that are not in urbanized areas. "Rural" refers to the population not classified as urban.

[3] NIPC used 1990 Census data on housing counts to estimate residential land consumption and Illinois Department of Employment Security data to estimate commercial and industrial land consumption.

Figure 20. Northeastern Illinois urban growth from 1980 - 1990.



loss of agricultural land, NIPC estimated that overall land consumption increased by at least 44%, or 362,240 acres, over the twenty-year period (Northeastern Illinois Planning Commission 1991 Annual Report). Figure 20 illustrates the municipal boundary changes between 1980 and 1990 for this area.

Similar estimates can be obtained from a relative comparison of data collected by the U.S. Department of Agriculture's Soil Conservation Service (SCS) nationwide inventory of land use. In looking at trends from 1967 to 1987, it should be noted that data is collected from representative sample points in each state and that the numbers are statistically reliable only at the state level. It should also be noted that different procedures were used to conduct the 1967 and 1987 inventories. However, lacking other data, the inventories can provide an indication of land use changes over the twenty-year period.

Using the SCS data, Figure 21 shows the 20-year trends in urban density — the number of people (urban population) per developed acre (urban and built-up land and rural transportation land[4]). In Cook County the density of persons per developed acre dropped from 15 to 10; in the collar counties it dropped from 4 to 3.5. The other MSA counties had a very slight decrease, while the balance of the state increased slightly from .8 to .9 persons per developed acre.

Combined, the six Northeastern counties (Chicago plus collar counties) saw urban density drop from 10 to 7 persons per developed acre. In the six-county area (Figure 22), only Will and McHenry counties show an increase in urban density, while in Cook, DuPage, Lake and Kane counties, urban density decreased.

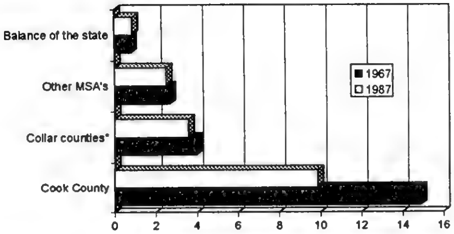


Figure 21. The number of people per each acre which has been 'developed'.
** Collar counties do not include Grundy and Kendall counties.*

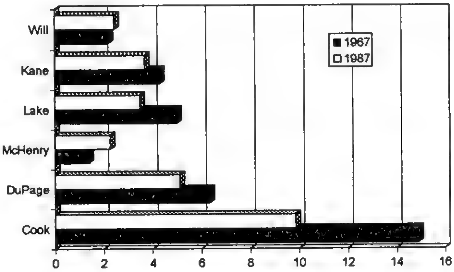


Figure 22. Persons per developed acre -- 6-county area.

Figures 23 and 24 show the percent change in developed acres, urban population and persons per developed acre over 20 years. Northeastern Illinois experienced a 57% increase in developed acreage compared to a 5% growth in population, resulting in a 33% drop in urban density. In the collar counties alone, developed acreage grew 76% compared to 59% growth in population, resulting in a 10% drop in density. This follows the trends of the other MSA's which experienced a 7% drop in density. The balance of the state saw a drop in both developed acres and urban population, resulting in an eight percent increase in urban density.

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[4] Urban and built-up land is nonfederal land consisting of residential, industrial, commercial and institutional land; construction sites; public administration sites; railroad yards; cemeteries; airports; golf course; sanitary landfills; sewage treatment plants; water control structures and spillways; other similar land uses; small parks (less than 10 acres) within urban areas; and highways, railroads and other transportation facilities in urban areas. Rural transportation includes all highways, roads and railroads outside urban areas; private roads to farmsteads, logging roads and other private roads. (1982 National Resources Inventory Basic Statistics)

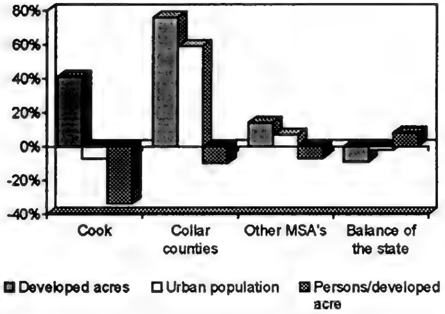

Figure 23. Percent change in urban population, developed land, and urban density: 1967-1987.

In the collar counties, McHenry County had the greatest population increase, 142%, compared to 47% growth in development, yielding a 64% increase in urban density. Will County grew 66% in population, 50% in development, and 11% in density.

Even with McHenry County's 64% increase in density, it is still lower than the other collar counties, 2.27 persons per acre in 1987 compared to 2.44 in Will, 3.49 in Lake, 3.69 in Kane, 5.12 in DuPage, and 9.86 in Cook.

Lake County experienced the greatest percent increase in developed acreage, up 122% compared to a population increase of 55%.

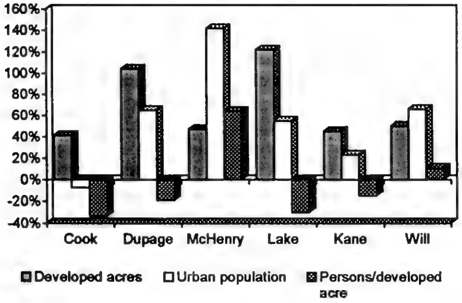

Figure 24. Percent changes — six-county Chicago area: 1967-1987.

HOUSING TRENDS

The trend towards more space for each person is particularly evident in the residential sector. In all areas of the state the number of persons per household is decreasing (Figure 25). Throughout the thirty-year time period, DuPage County has had the greatest number of people per household, followed by the other MSA's, Cook County and the rest of the state. That number continues to drop in all geographic areas, particularly in DuPage County where the median dropped from 3.7 to 2.8 persons, a drop of almost one person per household.

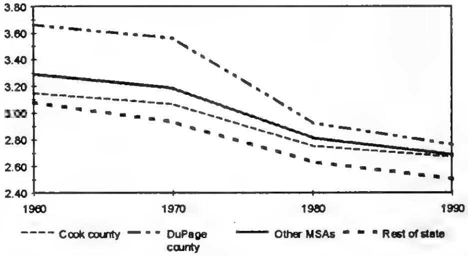

Figure 25. Persons per household, 1960 - 1990.

The trends in median number of persons per housing unit mirrors the dropping trend in household size. On a statewide basis, the median number of persons per unit has declined from 2.9 to 2.3 persons. At the same time, the median number of rooms per housing unit has increased, from 4.8 to 5.4 (Figure 26). This number will continue to grow as the average size of new housing grows. Nationally, between 1965 and 1969 the average size of a new housing unit was 1,659 square feet; between 1988 and 1990 it had grown to 2,482 square feet.

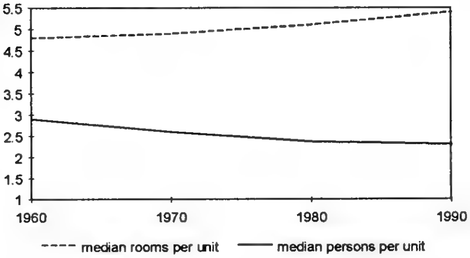

Figure 26. The median number of persons and rooms per housing unit.

LAND USE IMPACTS

Urbanization and the construction of new land forms can severely affect ecological systems. The following section briefly describes the potential impacts to agricultural lands, water systems and natural habitats.

Potential Impacts on Agricultural Land

After the first National Resources Inventory was conducted in 1977 it was estimated that Illinois had lost 100,000 acres of agricultural land yearly since World War II. (Werries, 1982) The balance of prime acreage remains threatened. The American Farmland Trust has estimated that 17 of the top 20 Illinois farming counties are in or adjacent to metropolitan statistical areas. (Riggle, 1992)

It is not just the possibility of land use conversion which threatens prime farmland in these counties. Covering large areas of land with buildings, parking areas and streets alters surface drainage. Farmland surrounding the developed area can subsequently be inundated with storm water runoff, damaging fields and crops. Water can also back-up in fields when field tile lines which extend through an area being developed are cut. As new highways cut farmland into smaller and smaller patches, it becomes much harder to work the land and to transport farm equipment.

For additional discussion of agricultural lands, see *Volume 3: Ecological Resources.*

Potential Impacts on Water Systems

Building an artificial landscape for human habitation can have a dramatic impact on water systems. Wetlands are frequently filled in, streams are channeled, levees are built and vegetation is removed. These actions alter the natural flow of streams and drainage ways and reduce natural floodwater retention capacity. They also alter aquatic and terrestrial habitat, open space, recreational opportunities and aesthetics.

As the land is sealed with impervious materials, precipitation which would previously have been absorbed by soils, vegetation and wetlands and then filtered to groundwater, now runs off the surface into local streams and rivers. The result — a much greater probability of downstream flooding, eroded stream banks, and sedimentation. With sedimentation comes water turbidity, which can block out the sunlight needed by stream plants and animals. Aquatic plants and animals are also affected when organic sediments deplete the oxygen in the stream, and when vegetation which shades the water is destroyed, thereby increasing water temperature.

In addition to all of the above, urban runoff carries pollutants such as de-icing salts and lawn fertilizer, pesticides and other petroleum products. For example, USEPA estimates that 67 million pounds of active ingredients of lawn care pesticides are applied to private lawns across the country. The rapid runoff of these pollutants overwhelms the natural filtering capacity of soils and vegetation, and streams quickly become polluted. (Mariner, 1988)

Figure 27 illustrates development along the Illinois River as of 1978. For additional discussion of water systems, see *Volume 2: Water Resources.*

Potential Impacts on Natural Habitats

Only those species with fairly general habitat and resource requirements can survive in urban corridors. Historically, local populations of wildlife were killed for food, fur and feathers or for predator control. In other instances, non-native species were introduced which either competed with native animals for limited resources, preyed upon the native animals, or exposed them to diseases and parasites to which the native organisms had no resistance.

For the relatively intact natural communities which still exist in and around urban areas the greatest threat is conversion of natural habitats to other uses. As urban activities spread outward, they destroy and fragment remnant functioning ecosystems. If natural corridors between large patches of natural areas are disturbed, the equilibrium between extinction and immigration among the remaining habitats are also disturbed.

Many factors affect the suitability of habitat for species. For example, removing understory foliage in parks and suburban developments removes habitat for numerous species, most conspicuously birds. Even planting exotic trees and shrubs in parks and along byways and converting open space to golf courses disrupts the natural distribution of biological diversity. (Murphy, 1988)

Figure 27. Urban encroachment on water resources - 1978 Peoria MSA.

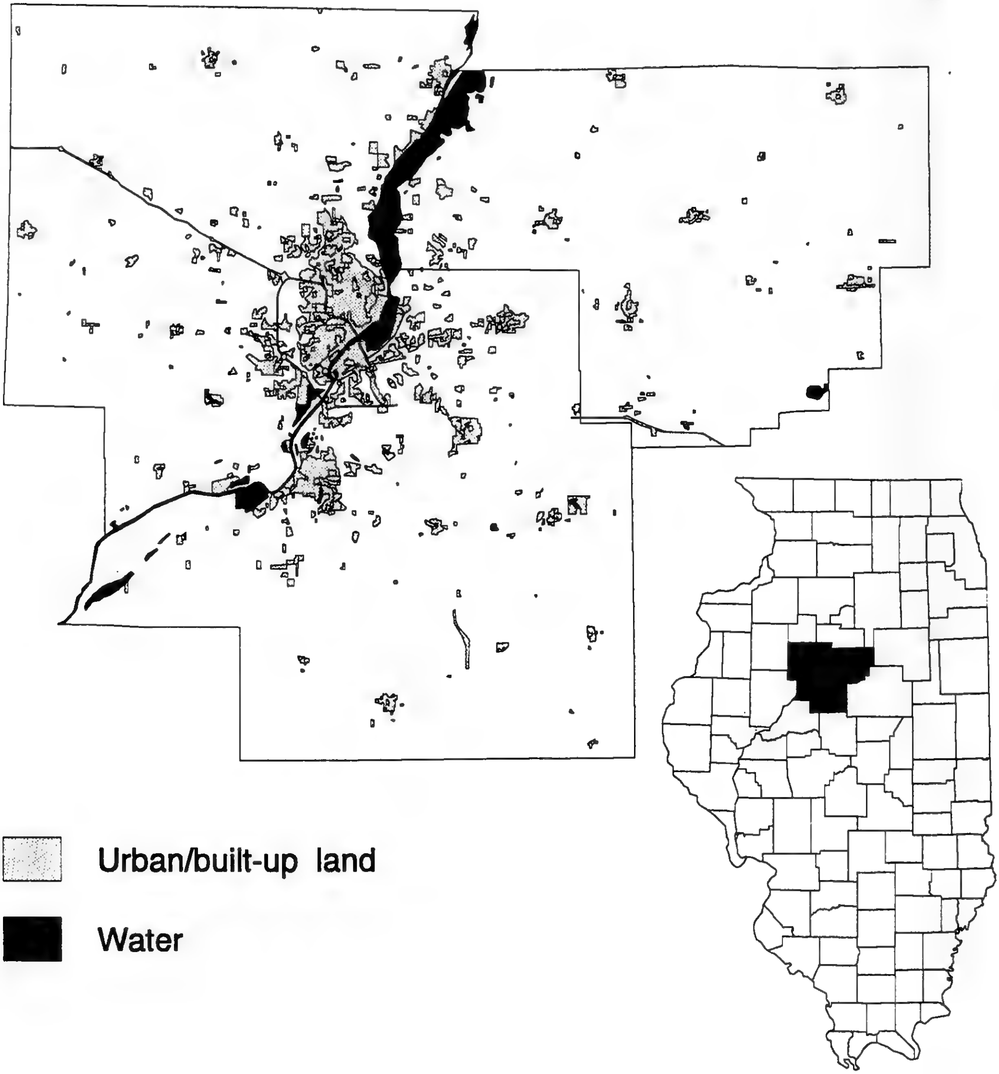

Figure 28 (p. 54) illustrates fragmented patches of forest in the Rock Island - Moline area as of 1976. For a more detailed discussion on habitat destruction, see *Volume 3: Ecological Resources.*

URBAN AIR EMISSIONS

Statewide Point Sources

Although emissions of criteria air pollutants from the urban dynamics category point sources — services, wholesale and retail trade, finance, insurance, real estate, and government — are small compared to other sectors of the economy, such as manufacturing and utilities, some sources are large enough to require a permit and be included in IEPA's Total Air System (TAS) database.

Using TAS data, Figure 29 shows statewide emissions of each pollutant. On a statewide basis, particulate emissions remain fairly even, with a slight decrease by 1989, while sulfur dioxide drops considerably in 1989. Nitrogen dioxide and hydrocarbon emissions increase slightly in 1986, and come back down again by 1989. Carbon monoxide increases slightly in each three-year period.

In looking at the TAS data by sector, the most significant change in carbon monoxide occurs in the service sector. From 1983 to 1989 service sector CO emissions grew from 21% of the total to 33% of the total. For particulate emissions, the wholesale sector was the major contributor — 88% in 1983, 85% in 1986, and 86% in 1989.

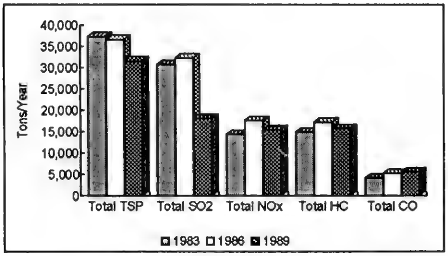

Figure 29. Statewide urban point source emissions, 1983, 1986 and 1989.

Chicago and Metro-East Areas

The Chicago and Metro-East areas fail to meet the Clean Air Act standard for ozone, and the state is required by federal law to prepare State Implementation Plans (SIP) to meet the standard. The emissions inventory for each area includes both point sources (permitted) and area sources (too small to be permitted) of volatile organic compounds, nitrogen oxides and carbon monoxide, all of which contribute to ozone formation. Using the methodologies described in the IEPA 1990 State Implementation Plans, a 20-year trend was calculated[5] for emissions of the three compounds in Cook County, five Chicago collar counties — Lake, Kane, McHenry, DuPage, and Will; and the Metro East counties of Jersey, Madison, Monroe and St. Clair.

Volatile Organic Compounds

Volatile organic compounds (VOCs) are emitted from a variety of sources within the urban environment. Figure 30 shows the contribution of the different urban sources of VOCs in the non-attainment areas. Consistently leading are architectural surface coatings — trade paints used primarily by homeowners and painting contractors to coat the interior and exterior of houses and buildings.

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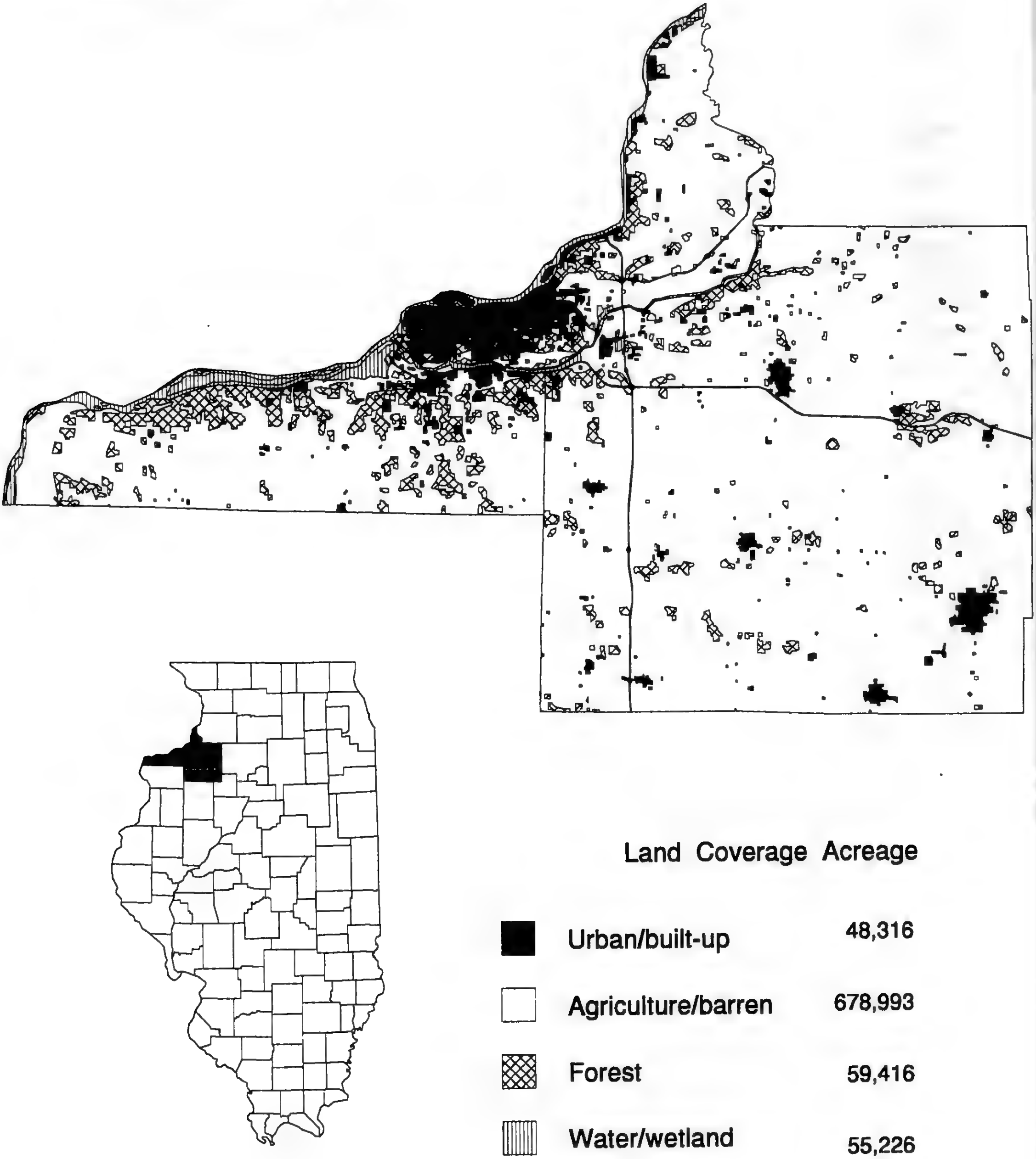
[5] Data adjustments were made to calculate the 20-year trends. For Stage I (service station loading), Stage II (vehicle refueling) and Underground Tanks — adjusted emission rate by Reid Vapor Pressure (RVP) and gasoline usage by county and used State Energy Data System and county Vehicle Miles Travelled to calculate gasoline quantities. For Architectural Coating, Automobile Refinishing, Cold Degreasing, Dry Cleaning, Graphic Arts, Commercial and Consumer Solvent Use, Bakeries, Fuel Combustion, and Structural Fires— adjusted by county population changes. For Traffic Maintenance and Painting and Asphalt Paving — adjusted by total highway mileage per county. For Lawn and Garden Equipment — adjusted by the number of single family residences per county and RVP changes. For Heavy Construction Equipment — adjusted by county SIC 16 employment and RVP changes.

Figure 28. Rock Island-Moline MSA 1976.



Land Coverage Acreage

■	Urban/built-up	48,316
□	Agriculture/barren	678,993
▩	Forest	59,416
▥	Water/wetland	55,226

Second are commercial and consumer solvents, another evaporative emission source. The categories within this group are personal products (i.e., hair spray), household products (cleaners), auto products (engine cleaners) adhesive products (glues), pesticides (bug sprays) and miscellaneous products. Third highest in emissions are graphic arts, which includes the printing of newspapers, books, magazines, fabric wall coverings and other materials.

Solvent degreasing, which removes grease, fats, oil, wax or soil from the surface of metal, glass or plastic articles, emits the fourth highest amount of VOC's. Vehicle refueling emits just slightly more than auto refinishing (repainting) operations. And although emissions from service station storage tank refueling peaked in 1980 (as did emissions from many of the sources), they fell significantly by 1990 because of regulations governing the capture of vapors during storage tank (Stage I) refueling.

Other sources of VOC's are combined into the category "other" and include traffic maintenance painting, dry cleaning, lawn and garden equipment, heavy construction equipment, underground tanks, asphalt paving, bakeries, structural fires, and commercial, residential and institutional fuel combustion.

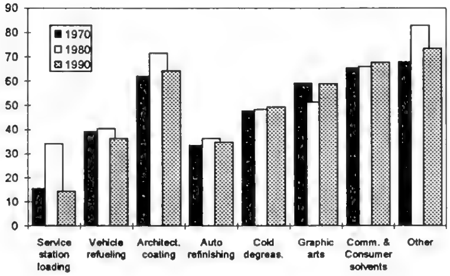


Figure 30. Voc emissions by source (tons per summer day).

According to Figure 31, total VOC emissions have remained constant for the Metro-East area; they have decreased in Cook County and increased in the five collar counties. The largest contributors after Cook County are DuPage and Lake counties.

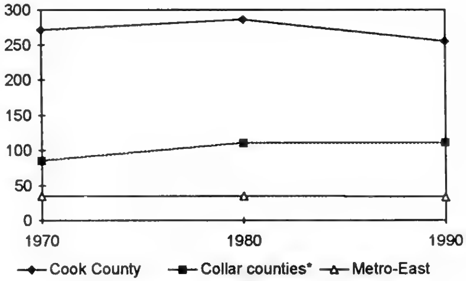


*Figure 31. VOC emissions (tons per summer day), 1970 -1990. * Collar counties do not include Kendall and Grundy counties.*

Nitrogen Oxides and Carbon Monoxide

Nitrogen oxides (NOx) and carbon monoxide (CO) are emitted during fuel combustion, which, in the urban category, includes residential, commercial and institutional fuel combustion, structural fires, lawn and garden equipment and heavy construction machinery. Figure 32 shows the 20-year trend of CO emissions in Cook County, the collar counties and the Metro-East area. Figure 33 shows the 20-year trend for NOx in the same areas.

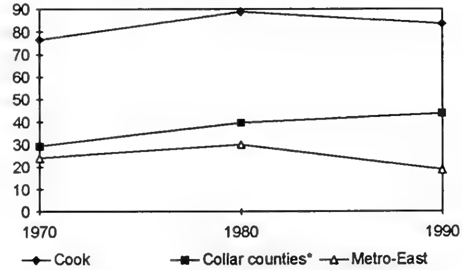


*Figure 32. Carbon monoxide emissions (tons per summer day), 1970-1990. * Collar counties do not include Kendall and Grundy counties.*

The overall trend for both parameters was an increase in emissions from 1970 to 1980, with the increase continuing to 1990 only for the collar counties.

Fuel combustion and heavy construction equipment produced more than 97% of the NOx emissions in all three years; lawn and garden equipment and heavy construction equipment contributed approximately 90% of the CO for all three years. The largest drop in emissions, both CO and NOx, occurred in heavy construction equipment in St. Clair County, which dropped 58% over the 20-year period.

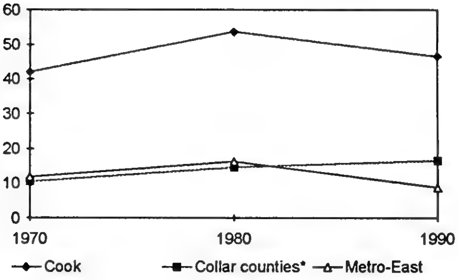


*Figure 33. Nitrogen oxide emissions (tons per summer day), 1970-1990. * Collar counties do not include Kendall and Grundy counties.*

CHLOROFLUOROCARBONS AND HALONS

Although chlorofluorocarbon (CFC) production will soon cease in the United States because of the compounds' potential to destroy stratospheric ozone, CFCs will still be emitted from existing equipment and materials for a number of years. Urban sources of CFCs include foams used in packaging, building insulation, roofing sheaths, refrigeration insulation, well and roof insulation, stock food trays, carry-out containers, egg cartons, cushioning and floatation devices.

CFCs are also found in commercial refrigeration, including cold storage; retail refrigeration; small refrigeration such as water coolers, ice makers and vending machines; and home appliances which includes refrigerators, freezers and dehumidifiers.

Halons are chemicals used in fire extinguishing equipment. On a per molecule basis, their ozone-destroying ability is far greater than the CFCs used in refrigeration, air conditioning and solvent applications. Approximately 70% of halons are in storage, awaiting use. Of the remainder, a small percentage is released under controlled conditions such as fire system testing, operator/installer training, accidental discharge, and servicing.

Table 1 shows the estimated annual emissions of CFCs and halons in Illinois. Table 2 shows the estimated CFC and halon bank in Illinois. A bank is the amount of CFCs or halons that is stored in existing appliances or materials.

The total bank of urban area CFC's and halons, adjusted by the Oxygen Depleting Potential (ODP) of the compound, is estimated to be 39,459 tons. The largest bank is the 24,037 tons of CFCs found in insulating foams. The bank of ozone depleting chemicals is expected to remain essentially unchanged for a number of years because most of the existing foam insulation, fire protection systems and cooling equipment are expected to be replaced slowly. (Kuhaneck, Licht and Marciniak, 1990)

Table 1. Estimated Illinois Annual CFC and Halon Emissions
(tons per year[a])

Sector	Installation	Use & Service	Disposal	Total
Foams	0	364	216	580
Large building a/c	5	392	101	498
Commercial refrigeration	15	216	130	361
Dry cleaning solvents	0	59	0	59
Home appliances	0	10	80	90
Halons	50	467	0	517
TOTAL	70	1508	527	2105

[a] *Emissions quantities have been adjusted for their ozone depleting potential.*

Table 2. Estimated Illinois CFC and Halon Bank

Sector	Total (tons)
Foams	24,037
Large building a/c	2,021
Commercial refrigeration	2,061
Home appliances	1,903
Solvents	0
Halons	9,437
TOTAL	39,459

INDOOR POLLUTION

The majority of people spend most of their time in closed, indoor environments which can be far more polluted than outdoor environments. Most of these indoor environments — homes, work locations, schools, and recreational facilities — have several sources of pollutants.

The trend to air tight buildings can increase indoor air pollution if ventilation is reduced and there is not sufficient outside air to dilute emissions or to carry them out of the building. The Bonneville Power Administration has estimated the percent reduction in air-exchange rates by house-tightening measures: storm windows, 6%; caulking, 3%; weather stripping, 1%; insulation, 10%; and duct sealing, 29%. The average air exchange rate of homes in the United States is 0.7 to 1.0 air changes an hour. In leaky homes it can be as much as 2 changes an hour, and in tight homes, 0.2 to 0.3 changes.

Even with a high exchange rate, some pollutants can be trapped by surfaces such as carpets, drapes and wall coverings and can be released into the air at a later time. In addition, high temperature and humidity levels can increase concentrations of some pollutants. (US EPA, 1988)

Most of the Illinois housing stock was built before energy conservation influenced air-tight construction practices (Figure 34). In the cooler Illinois climate, however, many older housing units have incorporated some type of weatherization practices which could reduce the air exchange rate and increase levels of indoor air pollution. On the other hand, other energy conservation practices, such as replacing inefficient faulty furnaces, would have a positive impact on the air quality. (Bierma, 1991)

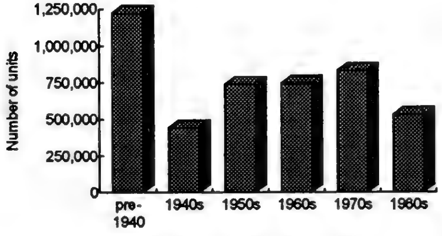


Figure 34. Housing units built per decade; 1980's figure includes the first three months of 1990.

The type of heating appliances and fuel used in a residence also influences indoor air quality. Combustion by-products are commonly found at significant concentrations where unvented heating units are used. Most units are heated by combustion of natural gas, fuel oil, LPG, kerosene or wood, all of which produce air pollutants that can degrade the indoor air. (US EPA, 1988) Using census information, Figure 35 illustrates the trends in residential fuel use in Illinois over the past 20 years.

Although utility gas far exceeds all other forms of fuel, electricity, the cleanest fuel relative to indoor air quality, has increased 6,000% in the 30-year period. On a national basis, more than one-half of homes built between 1984 and 1987 heat with electricity. One-third of the new units use a heat pump, which is operated by electricity. (It should be noted that the majority of the new home construction during this period took place in the southern and western regions of the country.) (DOE, 1987)

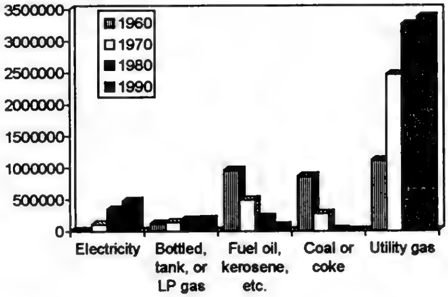


Figure 35. Illinois heating fuel use (by number of housing units).

Overall, the factors which affect indoor air quality are the source emissions, the air exchange rates, outdoor concentrations, and pollutant removal mechanisms, such as air filtration devices. The following list summarizes the major indoor air pollutants and their sources.

Biologic Organisms
Includes viruses, bacteria, fungal spores, pollens, arthropods (dust mites, cockroaches), and protozoa. Sources: mold, mildew, other fungi; humidifiers with stagnant water; condensing coils and drip pans; water-damaged surfaces and materials such as walls, ceilings, carpets; household pets, rodents, insects, humans.

Levels: Indoor levels of pollen and fungi are lower than outdoor levels except when indoor sources are present. Indoor levels of mites are higher than outdoor levels.

Tobacco Smoke

Includes a complex mixture of gases, vapors and particulate matter, including carbon monoxide, nitrogen dioxide, carbon dioxide, hydrogen cyanide, nitrosamines, aromatic hydrocarbons, benzo(a) pyrene, particles, benzene, formaldehyde, and nicotine. More than 4,500 compounds have been identified from burning tobacco.

Sources: cigarettes, pipes, cigars.

Levels: Homes with one or more smokers may have particle levels several times higher than outdoor levels.

Carbon Monoxide

Sources: unvented kerosene and gas heaters; leaking chimneys and furnaces; down-drafting from wood stoves and fireplaces; gas stoves; automobile exhaust from attached garages; incense, candles.

Levels: average levels in homes without gas stoves vary from 0.5 to 5 parts per million (ppm). Levels near properly adjusted gas stove can range from 5 to 15 ppm and near poorly adjusted stoves, 30 ppm or higher.

Nitrogen Dioxide

Sources: kerosene heaters, unvented gas stoves and heaters.

Levels: average levels in homes without combustion is about half that of outdoors; with them, levels often exceed outdoors.

Respirable Particles

Sources: fireplaces, wood stoves, kerosene heaters.

Levels: levels in homes without strong sources are the same as or lower than outdoor levels.

Volatile Organic Compounds

Includes alkanes, aromatic hydrocarbons, esters, alcohols, aldehydes, ketones.

Sources: paints, paint strippers, other solvents, wood preservatives, aerosol sprays, cleansers and disinfectants, fabric softeners, pens and markers, waxes and polishing compounds, moth repellents and air fresheners, stored fuels and automotive products, hobby supplies, dry cleaned clothing, adhesives, dyes, caulks, pesticides, building materials.

Levels: levels of several organics average two to five times higher indoors than outdoors. During and for several hours after activities such as paint stripping, levels can be 1000 times higher than outdoors.

Formaldehyde

Sources: pressed wood products such as particleboard, fiberboard and hardwood plywood wall paneling, and furniture made with these products; urea-formaldehyde foam insulation (UFFI), combustion sources and tobacco smoke; durable press drapes, other textiles and glues, some carpeting and carpet backing, household cleaners and deodorizers and cosmetics.

Levels: average concentrations in older homes without UFFI are generally below 0.1 ppm. In homes with new pressed wood products, level can be greater than 0.3 ppm.

Pesticides

Sources: products used to kill household pests and used on lawns and gardens that drift or are tracked inside the house.

Levels: preliminary research shows widespread residues in homes.

Asbestos

Sources: deteriorating or damaged insulation, fireproofing, or acoustical materials. Wall and ceiling insulation installed between 1930 and 1950, old insulation on heating pipes and equipment, some vinyl floor tiles, old wood stove door gaskets, drywall joint-finishing material and textured paint purchased before 1977, cement-asbestos millboard and exterior wall shingles, some sprayed and troweled ceiling finishing plaster installed between 1945 and 1973. (Bierma, 1991, and US EPA, 1988)

Levels: elevated levels where asbestos-containing materials are damaged or disturbed.

Lead
Sources: lead-based paint, house dust, auto exhaust, activities involving lead solder, lead dust from outdoor sources or contaminated soil tracked indoors.

Levels: lead dust levels can be 10 to 100 times greater in homes where sanding or open-burning of lead-based paint has occurred. It has been estimated that lead paint was used in about two-thirds of houses built before 1940; one-third of those built from 1940 to 1960, and some housing since 1960 (before it was banned from use). (US EPA, 1988) Based on the 1990 Census of Housing, and the above estimates of lead paint use, approximately 1.2 million Illinois houses could contain lead-based paint.

Radon
See following chapter.

CONCLUSION

The overall economic trends in the Urban Dynamics category (SICs 15-17 and 50-97) are generally upward. The services sector has grown the most, with output up 87% over 20 years and employment more than doubled. The statewide growth in service activities resulted in a slight increase in carbon monoxide emissions from that sector, from 21% to 33% of total CO emitted from the urban category.

Most economic and population growth is taking place in the collar counties around Chicago, spurring slight increases in emissions of ozone precursors — volatile organic compounds, nitrogen dioxide and carbon monoxide. In these growth areas, land is rapidly being developed, decreasing urban density but increasing the stress on surrounding ecosystems and agricultural lands.

Overall, Illinois' population grew slightly from 1970 to 1980 and has remained fairly static since. On a statewide basis, as many people live on the urban fringe as live in the central cities, with fewer than 15% living in rural areas. The majority of people still live in Cook County — although the numbers are declining— with the remainder of the population fairly evenly split among the collar counties, other metropolitan statistical areas, and the rest of the state.

The trend to lower urban density is particularly evident in the residential sector, as larger houses are being built for fewer people per household. Over 30 years, the median number of rooms per housing unit has increased from 4.8 to 5.4, while the number of persons per unit has declined from 2.9 to 2.3.

Although lower density within a house contributes to improved indoor air quality, tighter houses and the increased use of household chemical products can offset that improvement. However, data on indoor pollutants is inadequate to develop trends in this area.

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INDOOR RADON EXPOSURE

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INTRODUCTION TO INDOOR RADON

Since 1986 much information on indoor radon has been published in the scientific literature. A bibliography on the mobility of radon in the environment noted 2,000 reports published between 1951 to 1990 (Tanner, 1992). A second bibliography, concerned primarily with health effects, noted 1,700 reports (Harley, 1990). The tremendous quantity of literature that has appeared is a good indicator of the rapid emergence of indoor radon as an environmental health issue.

Radon-222, the isotope of main concern in the indoor radon issue, is the isotope which is generally being referred to when the term "radon" is used. Future references to radon in this report mean radon-222. Radon-222 is part of the uranium-238 decay series and has a half-life of 3.82 days. The parents, radium-226 and uranium-238, occur in trace amounts in most geologic materials, including soil. Because of its 4-day half-life, radon can migrate out of the soil, resulting in concentrations in outdoor air in the range of 0.1-0.3 pCi/L (Nazaroff and Sextro, 1989 and Nazaroff and Teichman, 1990).

The decay products of radon (radon daughters) are the short-lived radioactive isotopes polonium-218, lead-214, bismuth-214 and polonium-214. Decay through this series is via two alpha decays, two beta decays and several gamma-ray emissions which occur in rapid succession. It is the exposure to these radioactive species that creates the potential health risk.

The concentration of radon is measured in units of activity or number of decay events per unit time. Radiation levels are commonly reported in units of curies, where one curie is defined as 3.7×10^{10} disintegrations per second. The levels of radon that are commonly encountered are in the range of picocuries (pCi); one picocurie equals 0.037 disintegrations per second. The current United States Environmental Protection Agency (US EPA) guideline for indoor radon level is 4 pCi/L, expressed as an annual average. In terms of more conventional units, 4 pCi/L is equivalent to a radon mole-fraction of 2.8×10^{-18} or .0000028 parts per trillion (Stein, 1987).

RADON AS A HAZARD TO HUMAN HEALTH

Much confusion exists among the general public about the hazards of radon. This confusion results partly from the complex and highly technical nature of the subject. The apparent disagreement among the scientific experts concerning the absolute and relative risks of radon exposure has led to some uncertainty and ambiguity concerning the merits of the risk values adopted by the US EPA (Cohen, 1988, National Research Council, 1988, and Nero, 1989).

Public concern, fueled by the publicity associated with the discovery in the northeastern U.S. of high concentrations of radon in some homes, prompted the US EPA to establish a guideline for maximum average radon concentration of 4 pCi/L in U.S. homes and public buildings (US EPA, 1986). The US EPA, under a mandate from Congress passed in late 1988, is reviewing its radon guideline. This review could result in decreasing the indoor radon guideline to the range of 0.2 to 0.7 pCi/L. The Radon Pollution Control Act of 1988 states, "the national long-term goal of the United States with respect to radon levels in buildings is that the air within buildings in the United States should be as free of radon as the ambient air outside of buildings" (Congressional Record, 1988).

The details of the evidence for the health risks associated with radon have been reported recently by the National Research Council, Committee on the Biological Effects of Ionizing Radiation in the BEIR IV report (National Research Council, 1988). The concept of risk and the assignment of relative risk of the various pollutants that man is exposed to is beyond the scope of this report. The reader is referred to the following literature: National Research Council, 1988; Nazaroff and Teichman, 1989; and Nero, 1989 for more detailed discussions of the topic.

SOURCES OF RADON IN HOMES

Soil gas entry into the home is the dominant source of radon in indoor air (Hopke, 1987, Michel, 1987, and Nero, 1989). The radon concentration in soil will depend on the concentration of uranium and/or radium and the fraction of radon that can escape or emanate from a soil grain into the pore spaces. The radon concentration in the soil gas will be controlled by the amount of water present in pore spaces, the pore volume, and the grain size of the soil particles (Hopke, 1987 and Nazaroff and Sextro, 1989). Typical values of radon in soil air are 270 to 675 pCi/L with values in excess of 10,000 pCi/L observed (Hopke, 1987). The ease with which radon can infiltrate a structure will be controlled by the source potential of radon from soil, the openings in the structure, and the pressure differences between the structure and the surrounding soil (Hopke, 1987, Michel, 1987, and Nero, 1989). A pressure differential is established between a structure and its surroundings as a result of wind and temperature differences, mechanical ventilation systems such as forced air heating and cooling, and ventilation rates. These factors can lead to a "stack effect" in which soil gas is drawn into the house through openings in the substructure. Michel has estimated that if only 0.1% of the air in a building comes from soil gas that contains an average concentration of radon (about 500 pCi/L), an indoor radon level of 1.3 pCi/L could result (Michel, 1987).

INDOOR RADON LEVELS IN ILLINOIS

As the result of reports of elevated levels of indoor radon in Illinois, the Illinois Department of Nuclear Safety (IDNS) published a report from the Governor's Radon Task Force in the Spring of 1986 (IDNS, 1986). The report reviewed the available data on indoor radon levels in Illinois and concluded that indoor radon was not a major problem in Illinois, although about 25% of the tested residents had radon concentrations above the US EPA recommended action level. In recent updates, IDNS reported results of radon screening measurements in all 102 counties of Illinois (IDNS, 1988, and IDNS, 1992). The results indicate that about 31 percent of all radon measurements exceed the 4 pCi/L guideline, while only about 1 percent had levels above 20 pCi/L. The US EPA measured the levels of radon in Illinois in 1991 using the same protocol as used for 45 other states (IDNS, 1991). The US EPA study concluded that about 19 percent of the homes tested exceeded the 4 pCi/L guideline.

Table 1 gives a summary of indoor radon results for Illinois. Included in the table is the source of the data, the dates of coverage, mean, median, percent greater than 4 pCi/L, percent greater than 20 pCi/L, and the number of measurements. The results include measurements made with both long-term (2-weeks to 3-month tests) and short-term screening tests (2 to 4 days). The data from sources A, D and E and the US EPA are based on short-term screening tests, while the others are based on long-term measurements. The results of random screening surveys, such as those conducted by IDNS and US EPA, may not reflect a true average exposure because the tests have usually been conducted during the winter months when houses remained tightly closed and the indoor radon concentration would be the highest. The data sets from private companies may have a geographic bias, because increased testing is often a result of media attention, or promotional activity. This, in part, may explain the elevated results of data set A. The results are not separated by the location of the test in a particular home, although tests are usually made in the lowest livable area. In general, the data sets are consistent, with a mean of about 3.5 pCi/L, a median of about 2.5 and a percent greater than 4 pCi/L of about 23 percent. About 1 percent of the measurements exceed 20 pCi/L.

Table 1. Summary of Indoor Radon Measurements in Illinois

Data Source	Dates of Coverage	Mean (pCi/L)	Median (pCi/L)	% > 4 (pCi/L)	% > 20 (pCi/L)	n
IDNS*	1987-1991	3.9	2.7	31	1	4,127
US EPA*	1991	3.2	2.4	19	1	1,450
A*	Not Given	7.0	4.4	54	6	14,544
B*	1990-1992	3.6	1.9	26	2	12,987
C	1986-1988	3.2	2.6	22	1	1,197
D	1986-1989	3.0	2.3	17	1	3,087
E	1991-1992	3.9	2.3	30	2	745

n= Number of Measurements
* *Data used in Figures 2 and 3*

GEOLOGIC FACTORS IN THE PREDICTION OF INDOOR RADON

Several geologic factors must be evaluated to accurately determine the radon potential of geologic material (Otton, 1992, and Schumann, 1992). Both source and transport components must be established prior to any predictive mapping. The source component requires data on both the concentration and distribution of radium within the geologic material. The transport component requires data on the permeability to air, the water content, the grain size, and a knowledge of the presence of extensive joints or fractures in the surficial geologic material (Gilkeson, Cahill, and Gendron, 1988). Although many of these terms are not known in sufficient detail to predict the levels of radon in a particular home, several attempts to locate levels of elevated radon based on geologic factors have been made (Hasenmueller, 1988, Flood, et. al., 1990, Sprinkel and Solomon, 1990, Otton, 1992, and Schumann, 1992).

The United States Geological Survey (USGS), in cooperation with the US EPA, has produced geologic radon potential maps for the entire country. The model used to construct these maps is based on five factors, which are assigned point values. The higher the number of points scored, the greater the radon potential. The Radon Index Matrix used for these maps is shown in table 2. A score of 3 to 8 points predicts an indoor radon average value of less than 2 pCi/L, a score of 9 to 11 points predicts an indoor radon average value of 2 to 4 pCi/L, and a score of greater than 12 predicts an indoor radon average of greater than 4 pCi/L.

In the USGS/US EPA study, Illinois was divided into eight geologic regions and scores were assigned to each region (Schumann, 1992). The resulting map, as modified by IDNS, is shown in Figure 1. According to the study, most of Illinois has high or moderate potential for elevated radon (scores ranging from 9 to 13 points). Only extreme southern Illinois received a score of 8 points and had a low potential.

The USGS/US EPA Radon Index Matrix includes a number of factors that are inappropriate or unreliable. The inclusion of indoor radon data in a model that is meant to predict indoor radon levels is inappropriate. The goal of the U. S. Department of Energy's National Uranium Resource Evaluation (NURE) program aerial radiometric surveys was to determine uranium concentrations (eU) in geologic materials on a regional scale. In the case of Illinois, the actual NURE data covers about 2 percent of Illinois' total area. The "geology" term, as used, is subjective in that it defines most glacial materials as having a high radon potential. The parameters that control the amount of radon that emanates from soils are not easily mapped directly, and there have been few attempts to correlate these parameters with other characteristics of soils that are commonly mapped.

As a test of the map of Illinois radon zones, indoor radon measurements from the data sources noted in Table 1 were incorporated into the Illinois State Geological Survey Geographic Information System (GIS) and plotted according to zip code. The median level of indoor radon in each zip code area is plotted in Figure 2, using the same scale as Figure 1. Figure 2 illustrates the variable nature of the indoor radon measurements, and the number of areas within Illinois where no information is available. The figure also clearly illustrates that any area in Illinois could have indoor radon screening measurements that exceed 4 pCi/L.

In a preliminary attempt to locate "clusters" of elevated indoor radon measurements, the data were re-plotted in Figure 3 using different ranges. Only a few areas in Illinois (about 25 zipcode blocks) have results greater than 10 pCi/L. It is these areas of the state where more tests may be needed to confirm the screening results, and perhaps then the population at true risk can be identified. This conclusion is echoed by the Department of Energy and the US EPA, who in cooperation with the USGS, are beginning a study to search for "High-Radon Homes", which are defined as those homes that would likely exceed a screening measurement of 10 or 20 pCi/L (Gunderson, 1992).

RECOMMENDATIONS

(1) Continue to focus the state's radon program on high-risk geographical areas and high-risk exposure situations. This is critical given the limited financial resources of state government and the lack of response by the public at large. (IDNS, 1992).

Table 2. USGS/US EPA Radon Index Matrix
(Schumann, 1992)

Factor	1 point	2 points	3 points
Indoor Radon (average)	< 2 pCi/L	2 -4 pCi/L	> 4 pCi/L
Aerial Radioactivity	< 1.5 ppm eU	1.5 to 2.5 ppm eU	> 2.5 ppm eU
Geology	negative	variable	positive
Soil Permeability	low	moderate	high
Architecture	mostly slab	mixed	mostly basement

(2) Include geologic information to assist IDNS in evaluating areas in Illinois that have the greatest risk for high indoor radon concentrations, while also establishing the validity of any classification or map through a program of field testing.

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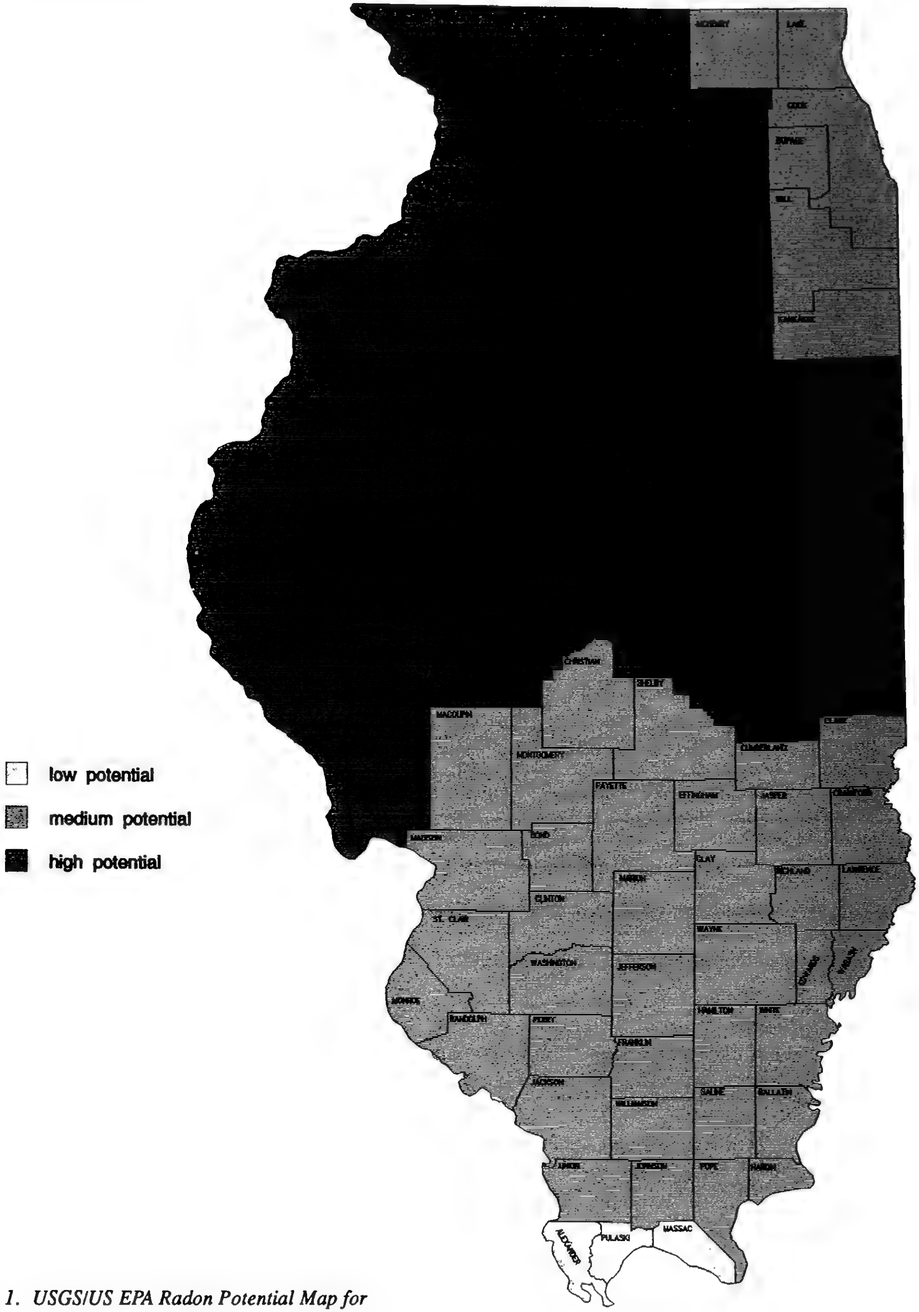

Figure 1. USGS/US EPA Radon Potential Map for Illinois based on the Radon Index shown in Table 2.

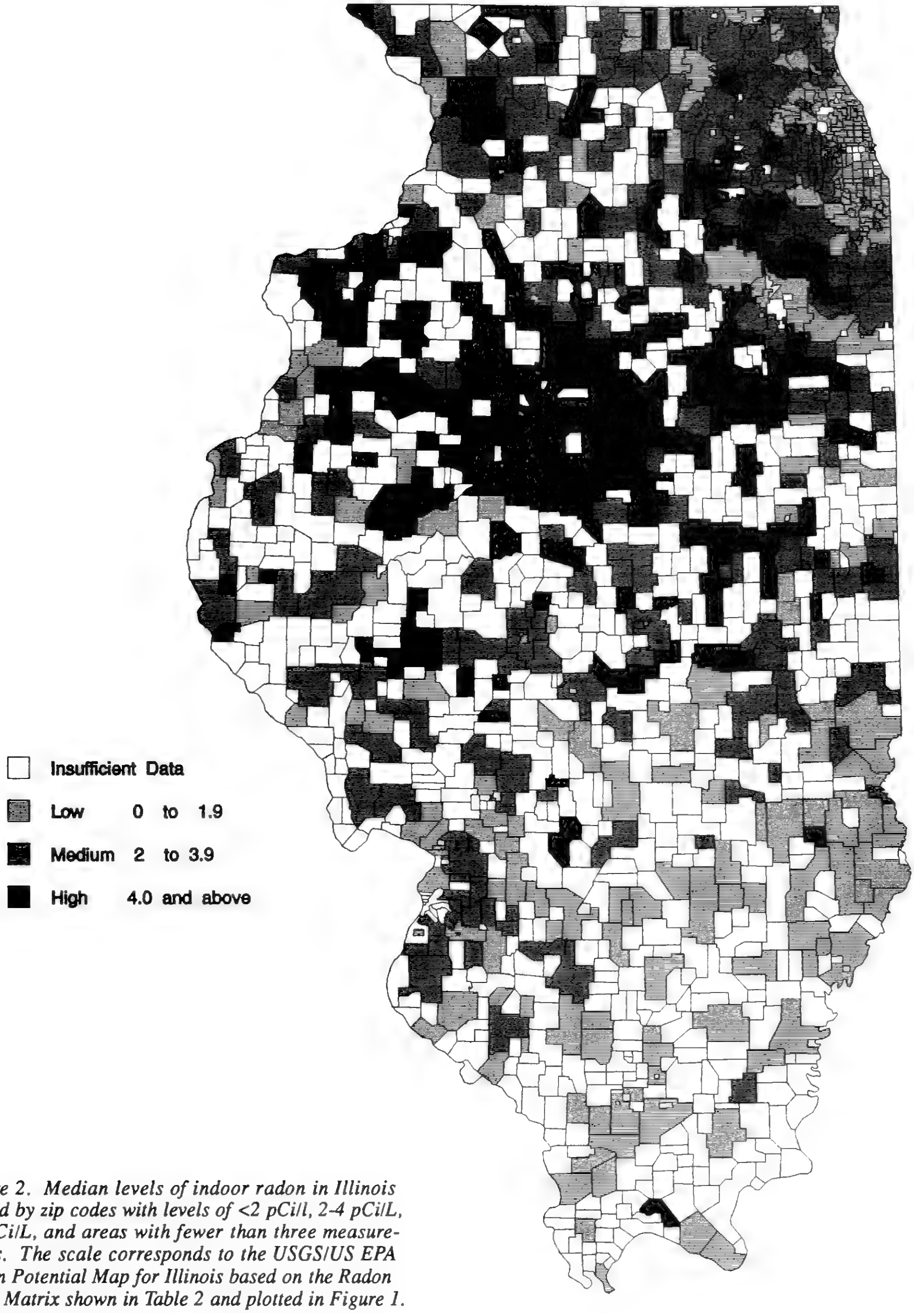

Figure 2. Median levels of indoor radon in Illinois plotted by zip codes with levels of <2 pCi/l, 2-4 pCi/L, >4 pCi/L, and areas with fewer than three measurements. The scale corresponds to the USGS/US EPA Radon Potential Map for Illinois based on the Radon Index Matrix shown in Table 2 and plotted in Figure 1.

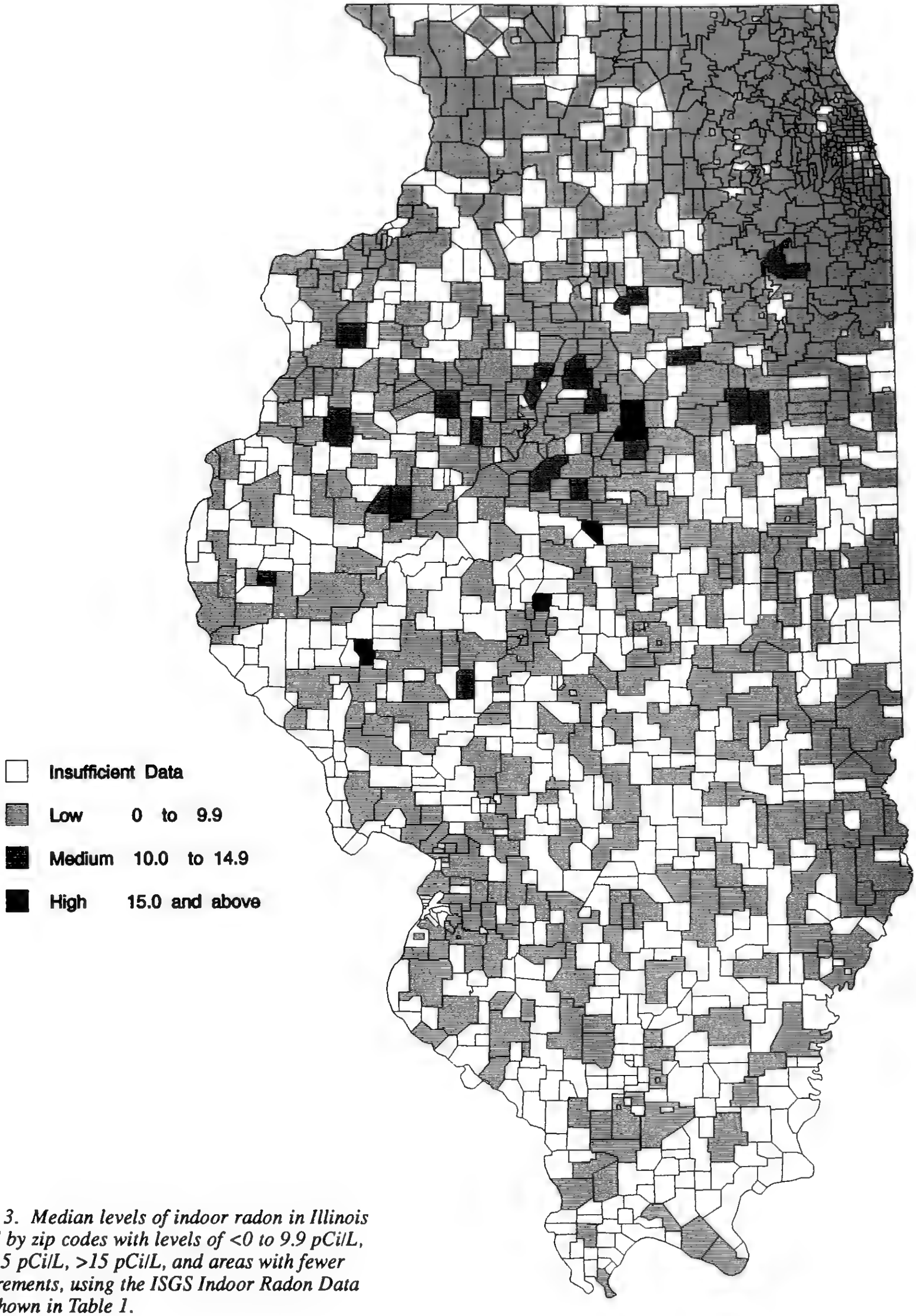

Figure 3. Median levels of indoor radon in Illinois plotted by zip codes with levels of <0 to 9.9 pCi/L, 10 to 15 pCi/L, >15 pCi/L, and areas with fewer measurements, using the ISGS Indoor Radon Data Base shown in Table 1.

WASTEWATER DISCHARGES

The Federal Clean Water Act of 1972 required every public or private facility discharging wastes directly into the waters of the United States to have a National Pollutant Discharge Elimination System (NPDES) permit. This permit establishes discharge limitations for specific pollutants, establishes schedules for plans to meet these limitations, and requires monitoring and periodic reporting on facility compliance. In Illinois, there are approximately 2696 NPDES facilities that receive wastewater discharge permits issued by the Illinois Environmental Protection Agency (IEPA). Of these facilities, 272 are major facilities that file discharge monitoring reports with IEPA. These reports are stored in USEPA's National Permit Compliance System (PCS) automated database.

The PCS data and accompanying analysis were provided by IEPA to develop trends in effluents. The analysis divided dischargers into municipal and non-municipal categories, with electric utilities and manufacturing facilities making up the non-municipal category. The analysis included only those major facilities that reported an equivalent number of sample measurements for a specific parameter every year from 1987 through 1992. The IEPA used the PCS load program to calculate loads associated with wastewater effluent. The pollutants analyzed are traditionally associated with municipal and non-municipal facilities and are reported by a significant number of major facilities.

FINDINGS

Major Municipal

Figure 1 illustrates statewide loadings of biological/carbonaceous biological oxygen demand (BOD/CBOD), total suspended solids (TSS), and ammonia. Fifty-five facilities were included in the load analysis of BOD/CBOD, with an estimated statewide loading in 1987 of approximately 24 million kilograms. This amount steadily decreased to 6.5 million kilograms, or a 72% decline, by 1992. This was the largest decrease of all the compounds analyzed.

Seventy-one facilities were included in the calculation of TSS trends. The estimated statewide loading for these facilities was approximately 26.8 million kilograms in 1987 and 15.5 million kilograms in 1992, a 42% decline.

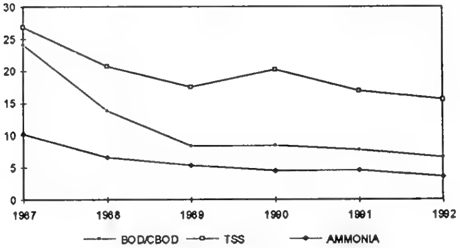

Figure 1. Estimated statewide pollutant discharge loading (million kilograms) for analyzed major municipalities.

Sixty-one facilities were included in the calculation of ammonia discharge trends. The estimated statewide loading for these facilities was approximately 10.2 million kilograms in 1987. This amount decreased 65% by 1992, to 3.5 million kilograms.

Sixty-one facilities were included in the calculation of chlorine residual trends. In 1987, the estimated statewide loading for these facilities was approximately 145 thousand kilograms and, by 1992, discharges dropped by almost 25%, to 109 thousand kilograms (Figure 2).

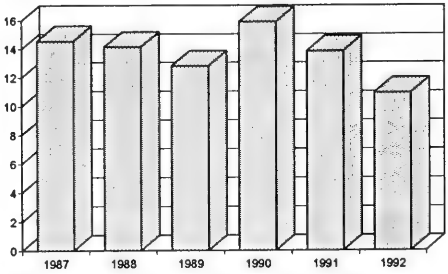

Figure 2. Estimated statewide chlorine residual loading (thousand kilograms) for analyzed major municipalities.

Major Non-Municipal

Figure 3 presents loadings in chromium, copper, cyanide and phenols from major non-municipal facilities. Thirteen facilities were analyzed for chromium discharge trends. Their discharge declined 46% from 3.1 thousand kilograms to 1.7 thousand kilograms. Eight facilities were included in the calculation of copper discharge trends. Copper declined 37% from 4 thousand kilograms to 2.5 thousand kilograms. Cyanide loads were analyzed for seven facilities, whose loadings declined 53% from 1.6 thousand kilograms to 765 kilograms. Loadings of phenols for 11 facilities declined 41%, from 1.6 thousand kilograms to 988 kilograms.

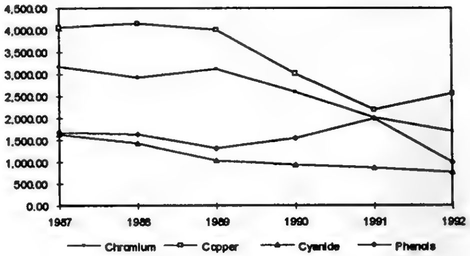

Figure 3. Estimated statewide pollutant discharge loading (kilograms) for analyzed major non-municipalities.

ACCIDENTAL RELEASES

Accidental releases of chemical products and wastes have been recorded in an IEPA Incident Database since the early 1970's. Figure 1 shows the number of incidents reported between 1972 and 1992. Even though it appears that incidents are increasing at a rapid rate, the increase is largely due to changes in reporting requirements (Goodner, IEPA, Sept. 1992).

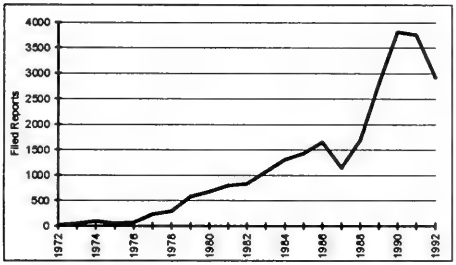

Figure 1. Number of reported incidents.

The database identifies incidents by responsible party, location (county), material involved (different names are frequently used for the same material, see Table 1) and an estimate of amounts released. (Note: between 1972 and 1981, 50% of the reports did not include the estimated quantity released. Over the entire 20-year period, 50% did not include units of measurement; of those that do, the units reported are not always consistent. In more recent years, data has been reported more consistently, primarily because of changes in reporting requirements and improved database design.) Although limited, the available data can provide a general picture of which materials are being released most often (Table 1), which counties experience the most reported incidents (summarized in Figure 2), and where and when large incidents have occurred (Table 2).

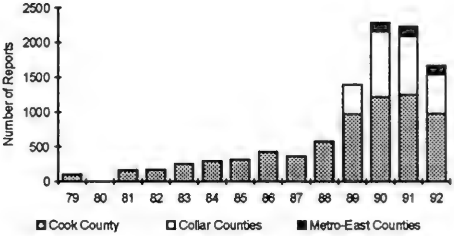

Figure 2. Geographic areas reporting the most incidents.

SUMMARY

Fuels are the most commonly reported materials involved in incidents. Anhydrous ammonia, polychlorinated biphenyls, sulfuric acid and chlorine are the other compounds most often reported. More than 200 reports listed the material spilled as being unknown and more than 100 fish kills were reported without identifying whether a spilled material caused the kill. The materials listed in Table 1 comprised only 20% of the reported incidents; most materials listed in the complete database were reported less than five times. And although most incidents have occurred in the populated counties around Chicago or St. Louis (Figure 2), large spills (Table 2) have occurred throughout the state, in rural as well as urban counties.

Table 1. Materials Reported Most Often

Material Released	Frequency
Gasoline	999
Diesel Fuel	561
Crude Oil	505
Fuel Oil	287
Oil	281
Anhydrous Ammonia	256
PCB	240
Gasoline (Unleaded)	218
Fuel Oil (Diesel)	190
Waste Oil	190
Sulfuric Acid	161
Diesel	134
Chlorine	116
Natural Gas	112
Unleaded Gasoline	105
Heating Oil	101

Table 2. Major Spills

County	Year	Material	Amount	Units
Douglas	1990	Supernate From Process	750,000	Gallons
Madison	1980	Waste Oil	700,800	Gallons
Cook	1986	Choke White Grease	690,000	Pounds
Clark	1979	Pesticide	650,000	Gallons
Crawford	1977	Storm Water	500,000	Gallons
De Witt	1979	Fertilizer	500,000	Gallons
Madison	1983	Spent Sulfuric Acid	500,000	Pounds
Warren	1985	Hog Waste	500,000	Gallons
Kane	1986	Crude Oil	500,000	Gallons
La Salle	1988	Ammonium Nitrate	500,000	Gallons
McLean	1988	Wastewater C/W Diquat	500,000	Gallons
Madison	1989	Hydrocarbons (Light)	500,000	Pounds
Carrol	1985	Manure	450,000	Gallons
Piatt	1990	Sewage (Raw)	450,000	Gallons
Adams	1986	Anaerobic Digester Sludge	400,000	Gallons
Alexander	1986	#4 Fuel Oil	378,000	Gallons
Will	1983	Aluminum Sulfate	350,000	Gallons
Alexander	1985	Fuel Oil	322,000	Gallons
La Salle	1979	Potassium Permanganate	300,000	Gallons
Will	1979	Raw Sewage	300,000	Gallons
Cook	1982	Oil #5	300,000	Gallons
Cook	1988	Crude Coke Oven Tar	300,000	Gallons
Logan	1988	Sewage	300,000	Gallons
Will	1990	Gas Oil (Released)	285,000	Pounds
Cook	1980	Hydrogen Chloride	261,260	Gallons
Cook	1973	Ethylene	254,000	Pounds
Madison	1985	Sulfuric Acid 88%	240,000	Pounds
Christian	1992	Ammonium Sulfate	225,000	Gallons
Cook	1979	Gasoline	217,245	Gallons

Source: IEPA Incident Database

GREENHOUSE GAS EMISSIONS

Five pollutants contribute to global warming — carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), nitrogen oxide (NOx), and carbon monoxide (CO). (See Table 1 for sources of each gas.) Nitrogen oxide and carbon monoxide, minor greenhouse gases, are covered in the sections on manufacturing, transportation and urban dynamics. In this section, methane, nitrous oxide and carbon dioxide will be covered.

(Although chloroflourocarbons (CFCs) are also greenhouse gases, research indicates that they have no net effect on climate due to their cooling effect via ozone depletion, and therefore are not included in this discussion.)

The Illinois Inventory of Greenhouse Gas Emissions[1] provides emissions data for 1970, 1980, and 1990. Table 2 lists emissions of each gas and their CO_2 equivalents. (CO_2 equivalents are used because one ton of methane has 11 times, and one ton of nitrous oxide has 270 times, the heat-trapping potential of CO_2.) Over the twenty year period, emissions of all three gases have declined, with total emissions dropping 18%, from 318 million tons to 260 million tons.

Table 2: Illinois Greenhouse Gas Emissions (thousand tons)

	1970	
Gas	Emissions	CO_2 equivalent
CO_2	284,809	284,809
CH_4	2,296	25,261
N_2O	29	7,919
Totals		317,989
	1980	
Gas	Emissions	CO_2 equivalent
CO_2	270,562	270,562
CH_4	2,200	24,415
N_2O	27	7,280
Totals		302,257
	1990	
Gas	Emissions	CO_2 equivalent
CO_2	231,530	231,530
CH_4	2,017	22,187
N_2O	24	6,416
Totals		260,133

Table 1: Sources of Greenhouse Gas Emissions

CO_2	CH_4	N_2O	NOx	CO
Fossil Fuel Combustion Production Processes Natural Gas and Oil Systems Landfills Land Use Change Biomass Fuel Combustion	Agricultural Crop Waste Burning Domesticated Animals Natural Gas and Oil Systems Landfills Coal Mining Animal Manure	Fossil Fuel Combustion Agricultural Crop Waste Burning Fertilizer Use Land Use Change	Fossil Fuel Combustion Agricultural Crop Waste Burning	Fossil Fuel Combustion Agricultural Crop Waste Burning

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[1] The U.S. EPA *States WorkBook: Methodologies for Estimating Greenhouse Gas Emissions* was used to develop the inventory.

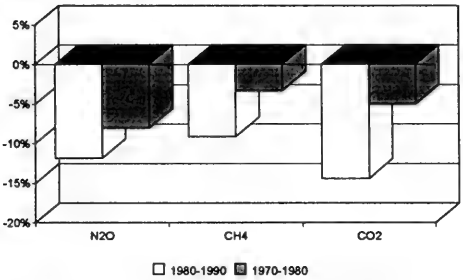
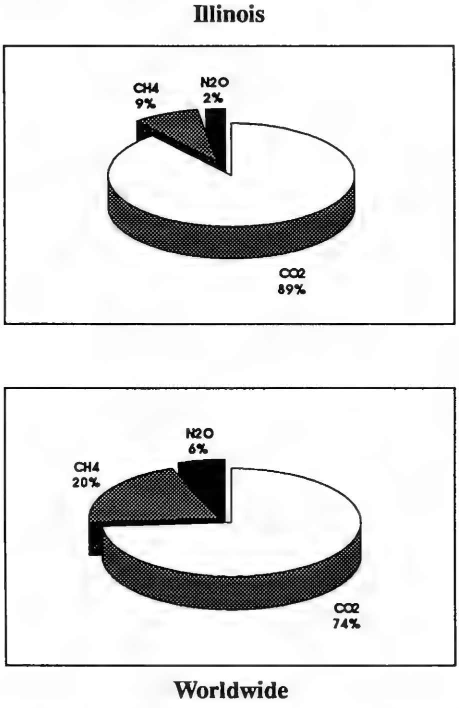


Figure 1. Percent changes in CO_2 equivalents - Illinois greenhouse gas emissions.

Compared to worldwide emissions (Figure 2), Illinois emissions contain a higher percentage of carbon dioxide. Methane contributes less to the total, primarily because rice, a major methane emitter, is not grown in Illinois.



Illinois

Worldwide

Figure 2. Composition of greenhouse gas emissions, 1990.

Fossil fuel combustion emits 88% of the total greenhouse gas emissions (Figure 3). Landfills and coal mining are the next largest contributors, primarily because of their methane emissions. Although land-use change has operated as a CO_2 sink (uptake and use of carbon dioxide) in the past, it is currently causing some emissions of CO_2 because of greater tree mortality and less new growth.

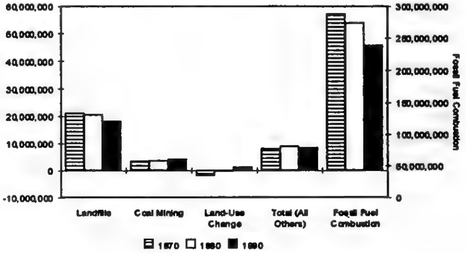


Figure 3. Illinois greenhouse gas emissions (tons) in CO_2 equivalents, 1970 - 1990.

CO_2 EMISSIONS

Emissions of carbon dioxide dropped 19% between 1970 and 1990, primarily because increased use of nuclear energy and energy efficiency reduced the amount of fossil fuels burned in the state. Fossil fuel combustion has consistently been the largest emitter, 98%, of CO_2 over the past 20 years. In 1990, it contributed 228 of the 234 million tons of carbon dioxide emissions (Figure 4). (Note: In 1970 and 1980 the land-use change category actually provided a "CO_2 sink," whereby more carbon dioxide was needed for growing trees. Because land-use change emissions are negative in these years, fossil fuel emissions in Figure 4 are lowered by the amount of land-use change uptake).

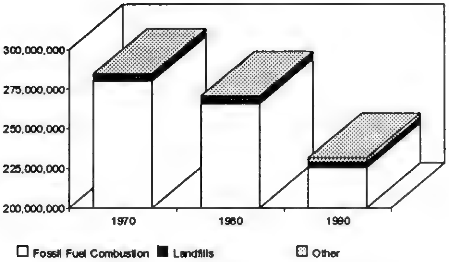


Figure 4. Illinois CO_2 emissions (tons) by source, 1970 - 1990. (Note: "Other" includes Production Processes, Land-Use Change, and Natural Gas and Oil Systems.)

CH_4 EMISSIONS

Over the past 20 years methane emissions have been reduced by 12%. Of the six sources of methane emissions, landfills contribute the most, 73%, of the statewide total. Coal mining is the next largest contributor at 12% (Figure 5). Most of the reduction occurred in the landfill category because yard wastes were banned from Illinois landfills in 1989. Other significant reductions occurred in the domesticated animals and animal manure categories because fewer head of cattle and pigs are being managed on Illinois farms.

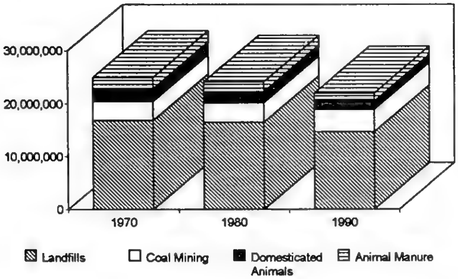


Figure 5. Illinois CH_4 emissions (tons) by source, 1970 - 1990.

N_2O EMISSIONS

Overall statewide emissions of N_2O dropped by 19%, or 1.5 million tons (CO_2 equivalent), during the 20-year period. (Figure 6) While emissions from the fertilizer use category increased between 1970 and 1980, they were more than offset by decreases in fossil fuel combustion emissions. Fertilizer use had gone up during these years because farmers increased grain production for export to the former Soviet Union. Use went down slightly after 1980 because of a mild agricultural recession, concern about environmental impacts, and increased use of conservation and no-till farming. In the fossil fuel category, although emissions from automobiles were up slightly (emission controls for CO, NOx, and VOCs caused an increase in emissions of N_2O), overall emissions were down, primarily because the industrial and commercial use of coal declined.

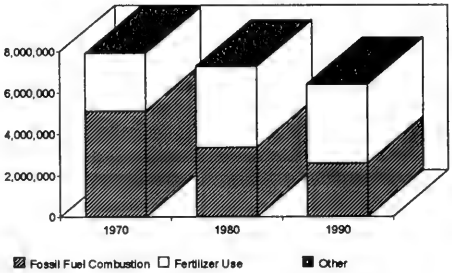


Figure 6. Illinois N_2O emissions by source, 1970 - 1990. (Note: "Other" includes Agricultural Crop Waste Burning and Land-Use Change.)

CONCLUSION

Three of the major greenhouse gases emitted in Illinois are carbon dioxide, methane, and nitrous oxide, with carbon dioxide from fossil fuel combustion contributing the bulk of emissions. Statewide emissions of these gases have declined significantly during the last twenty years for several reasons. 1. Illinois has moved from coal-intensive to nuclear-intensive production of electricity. 2. Industrial, commercial, and residential use of oil and coal has declined, while use of natural gas, which has a lower emission factor, has increased. 3. Energy efficiency improvements have reduced energy use. 4. Landfills emit less methane because, in spite of increases in population and waste generation, less waste is being landfilled — yard wastes have been banned from disposal and more materials are being recycled. Additional declines are expected as larger landfills install gas recovery systems.

HUMAN EXPOSURE TO AIR POLLUTION

This chapter presents trends in human exposure to environmental pollutants in ambient air. It does not attempt to provide a statewide risk assessment or to predict or interpret the health impact of the exposure. The requisite data was not available to develop such an assessment.

A simple procedure was developed to assess exposure. Ambient measurements for criteria air pollutants were compared to their legal standards[1] (Table 1); those above the standard were assumed to present some risk and those below the standard were assumed to present no risk.[2] (Figure 1) The duration and magnitude of the exposure, and the interaction of multiple pollutants, was not factored into the analysis. Data for the analysis was taken from the Illinois Environmental Protection Agency's (IEPA) annual reports on air quality, 1978 through 1990, and provided by the State Water Survey in a Geographic Information System (GIS) format, which allows for both mapping and attribute analysis. The criteria air pollutants that were examined include sulfur dioxide (SO_2), ozone (O_3), lead (Pb), carbon monoxide (CO), nitric oxides (NOx) and total suspended particulate (TSP). (See *Volume 1: Air Resources* for discussion of the data and ambient trends.)

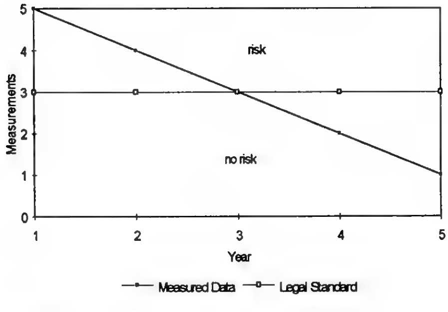


Figure 1. Example of 'Risk'-'No Risk' assumption.

To develop population exposure estimates, a GIS was used to place a one-mile buffer around air quality stations which had at least one measurement recorded above the legal standard. A five-mile buffer was also considered, but measurements from stations within five miles of each other were rarely similar -- one measurement would be above and the others below the standard. This indicated that a five-mile buffer might overcount the number of people exposed to the pollutant. Figure 2 illustrates the one- and five-mile buffers.

Census data was used to estimate the population living within the buffer -- the 1980 Census was used for the 1978 - 1985 ambient data; the 1990 Census was used for the 1986 - 1990 data.

The one-mile radius is merely used to estimate exposure. In actuality, exposure is far more complicated and exposure levels would not be uniform within the one-mile circle. Factors which influence exposure include the pollutants' physical and chemical properties, weather conditions (temperature, humidity, wind direction and velocity) and distance and direction from the source. In addition, most of the population is mobile, i.e., not stationary, and is exposed to changing environments.

The following sections discuss each of the six pollutants examined: their historical ambient levels, their impact on human health, and an estimate of the number of people exposed to levels above the legal standard.

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[1] It was originally envisioned that the procedure could be modified and applied to those compounds for which no legal standard exists and for which only estimates of ambient measurements or emissions would be available. However, data was not readily available and time and resources only allowed for examining the criteria air pollutants.

[2] It is important to note that the assumptions used for this analysis are significantly different than those used in regulatory programs.

Figure 2. *Comparing 1 and 5 mile buffers around ambient air quality monitoring sites.*

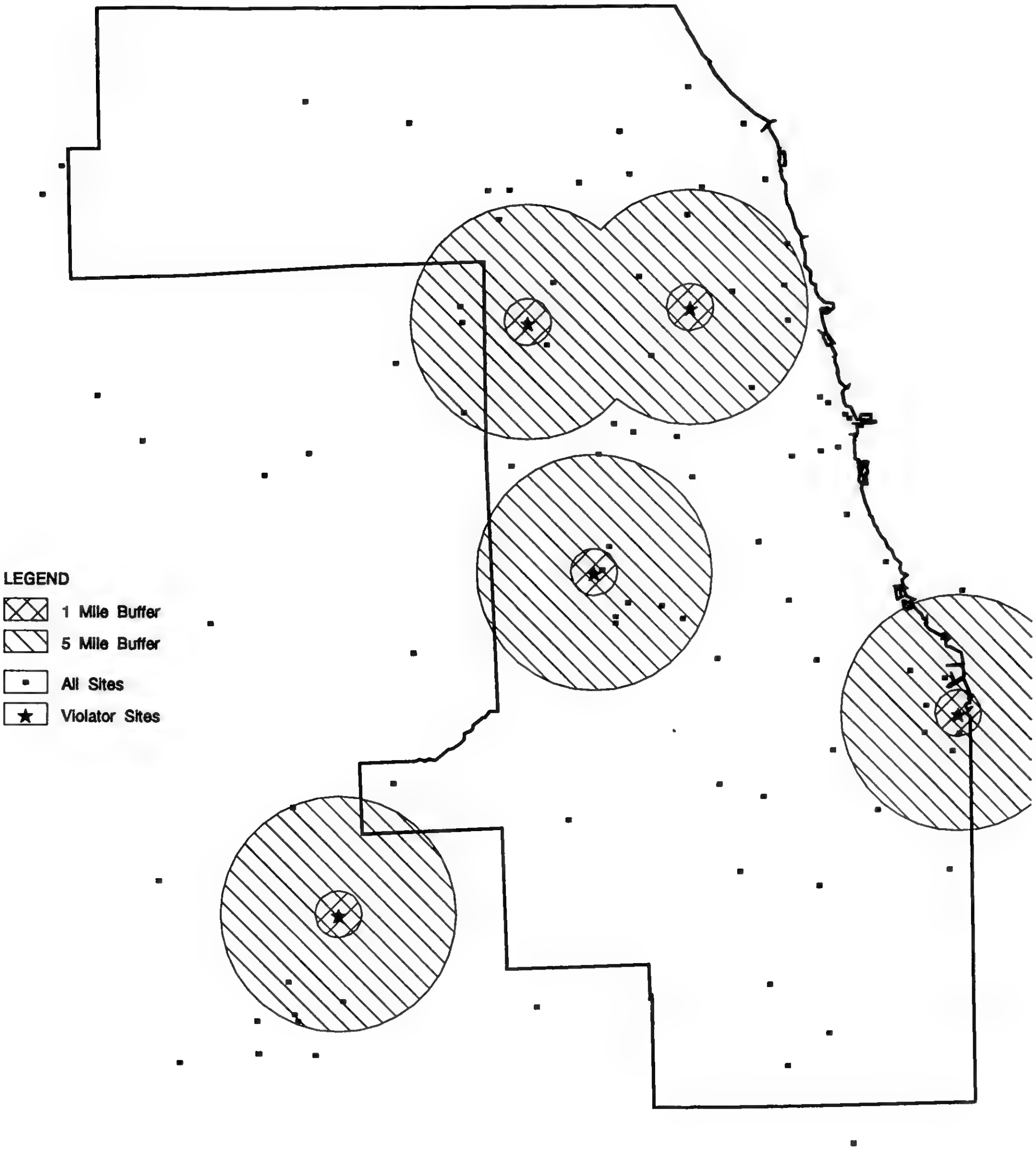

Table 1. Illinois Ambient Air Quality Standards[a].

Standard (25 C and 760 mm Hg)

Averaging Time	Primary	Secondary
Particulate Matter TSP[b]		
Annual Geometric Mean	75 $\mu g/m^3$	60 $\mu g/m^3$
24-hour	260 $\mu g/m^3$	150 $\mu g/m^3$
Particulate Matter 10 micrometers (PM_{10})[c]		
Annual Arithmetic Mean	50 $\mu g/m^3$	50 $\mu g/m^3$
24-hour	150 $\mu g/m^3$	150 $\mu g/m^3$
Sulfur Oxides (SO_2)		
Annual Arithmetic Mean	80 $\mu g/m^3$ (0.03ppm)	None
24-hour	365 $\mu g/m^3$ (0.14ppm)	None
8-hour	None	1300 $\mu g/m^3$ (0.5ppm)
Carbon Monoxide (CO)		
8-hour	10000 $\mu g/m^3$ (9ppm)	10000 $\mu g/m^3$ (9ppm)
1-hour	40000 $\mu g/m^3$ (35ppm)	40000 $\mu g/m^3$ (35ppm)
Nitrogen Dioxide (NO_2)		
Annual Arithmetic Mean	100 $\mu g/m^3$ (0.053)	100 $\mu g/m^3$ (0.053)
Ozone (O_3)		
1-hour/day	235 $\mu g/m^3$ (0.12ppm)	235 $\mu g/m^3$ (0.12ppm)
Lead (Pb)		
Quarterly Arithmetic Mean	1.5 $\mu g/m^3$	1.5 $\mu g/m^3$

a) IEPA, 1989. Title 35: Environmental Protection. Subtitle B: Air Pollution, Chapter I: Pollution Control Board. State of Illinois Rules and Regulations.
b) The TSP standard was an Illinois standard only.
c) The federal standard for PM_{10} replaced the state TSP standard on July 1, 1987.

SULFUR DIOXIDE

Sulfur dioxide (SO_2) is an atmospheric pollutant which results from combustion processes (primarily involving fossil fuels containing sulfur compounds), petroleum refining, sulfuric acid manufacture, and smelting of ores containing sulfur. Reducing sulfur dioxide pollution levels can generally be achieved by substituting high sulfur fuels with low sulfur fuels or by using chemical sulfur removal systems.

Once in the atmosphere some sulfur dioxide can be oxidized (either photochemically or in the presence of a catalyst) to SO_3 (sulfur trioxide), a highly hygroscopic vapor (1-10%/hr). The SO_3 rapidly combines with water vapor to produce an ultra fine droplet aerosol or mist of H_2SO_4 sulfuric acid (acid rain). Other basic oxides combine with SO_3 to form sulfate aerosols.

Health Effects

Many of the resultant health problems attributed to SO_2 may be a result of the oxidation of SO_2 to other compounds. Highly water soluble SO_2 is efficiently captured in the upper respiratory tract during normal inhalation. However, under exercise, there is less residence time in the upper airways and inhaled SO_2 can penetrate to the depths of the lungs and cause various lung diseases, or exacerbate pre-existing respiratory diseases like asthma, bronchitis, and emphysema. The irritant response increases two to three times in the presence of particulate matter capable of oxidizing sulfur dioxide to sulfuric acid. In addition, epidemiological evidence demonstrates statistically significant associations between SO_2 and rates of morbidity and mortality (Lippmann, 1992).

Historical Levels

Several sources were reviewed to determine pre-1978 levels of SO_2. The data was not used in the exposure assessment because comparisons to more recent data would be difficult if not impossible. However, the data does provide a limited historical perspective. For example, one of the early efforts to collect air quality data was the Continuous Area Monitoring Program (CAMP). The CAMP network was operated by the US Department of Health, Education and Welfare's Public Health Service in cooperation with state and local agencies. CAMP reports included monthly and annual summaries of hourly average concentrations. Data from 1964 and 1965 for the Chicago area reported the maximum 24-hour concentrations of SO_2 at 0.67 ppm (parts per million) and 0.55 ppm. Illinois' legal standard for SO_2 is 0.14 ppm for a twenty-four hour period (see Table 1). The average monthly concentrations from the CAMP Chicago area network from 1964 to 1968 were: 1964, 0.175 ppm; 1965, 0.130 ppm; 1966, 0.084 ppm; 1967, 0.125 ppm; and 1968, 0.117 ppm (USEPA, 1972).

Exposure Assessment

The exposure assessment for the years 1978 to 1990 is presented in Figure 3. The legal standard used for the analysis was the twenty-four hour maximum. During the 13-year time period, SO_2 monitoring sites were operated in twenty counties for at least one year.

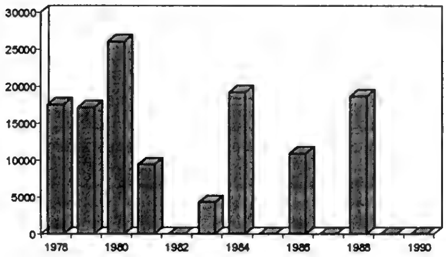

Figure 3. Estimated number of people exposed to significant levels of ambient SO_2.

From 1978 through 1981, the standard was consistently exceeded, with more than 25,000 people exposed in 1980. Thereafter, exposure to SO_2 quantities above the standard fluctuated between zero and 20,000 people. In 1978 and 1984, Madison and Cook counties each had at least one exceedance, and in 1980, when the greatest number of people were exposed, sites in St. Clair, Sangamon, and Cook exceeded the standard.

LEAD

Lead (Pb) can be present in the environment in a variety of forms (Boline, 1981) that include: 1) free hydrated ions; 2) ion-pair salts/complexes; 3) organic complexes/chelates; 4) undissolved compounds; and 5) surface-adsorbed material. Although sources such as lead smelters, battery manufacturers, and iron and steel producers can contribute significant amounts of lead to their immediate vicinities, atmospheric lead typically originated from combustion of leaded gasoline. Due to the harmful effect of lead on public health, the Clean Air Act of 1970 authorized the Administrator of the U.S. Environmental Protection Agency (USEPA) to control or prohibit the manufacture and sale of leaded motor vehicle fuels or fuel additives. USEPA ordered that unleaded gasoline be generally available and established a five-year reduction schedule for leaded gasoline (USEPA, December 1973).

Health Effects

Lead is a stable compound which persists and accumulates in the environment and in humans, with children being the most sensitive to its adverse effects. It enters the human body through ingestion and inhalation with consequent absorption into the blood stream and distribution to all body tissues. Lead absorption is dependent on several factors such as the organic form, the particle size of the lead source, and dietary intake (Lippmann, 1992; IEPA, May 1992). Central nervous system effects are the most significant in terms of health and performance (Klaasen et al., 1986).

Historical Levels

For the period 1957-1966, on an annual average basis, urban concentrations of lead in Illinois ranged from 1 to 3 $\mu g/m^3$, and non-urban concentrations ranged from 0.1- 0.5 $\mu g/m^3$ (Air Pollution Measurements of the National Air Sampling Networks, 1957-61 and 1963; Air Quality Data from the National Air Sampling Networks, 1964-65 and 1962). For the period 1967-69, at least 27 areas, including Chicago, reported maximum quarterly averages in excess of 2 $\mu g/m^3$ (National Academy of Science-National Research Council, 1971). One Chicago monitor showed a concentration of 2.8 $\mu g/m^3$ averaged over the four fall months of 1971 (Chicago Ambient Air Quality Data, 1971).

Prior to the phase out of leaded gasoline, the concentration of lead in the ambient air was often closely correlated with the density of automotive traffic. Ambient air levels approaching 10 $\mu g/m^3$ had occurred within 19 feet of a highway with a traffic volume of 58,000 vehicles per day (Daines, et al. 1970), while concentrations as high as 25 $\mu g/m^3$ had been measured in heavy traffic (Ludwig, 1965). A 1972 study of two sites in Chicago (Jefferson Park and National Lead Plant) revealed that the calculated average lead values in the air ranged from 1.26 $\mu g/m^3$ to 8.53 $\mu g/m^3$ (Monitoring of Hazardous Substances, 1972).

Exposure Assessment

Figure 4 illustrates the estimated population exposed to 'risk' levels of lead between 1978 and 1990. According to the statewide data, no measurements have exceeded the legal standard since 1982, primarily because of the phase out of leaded gasoline. For the most part the exceedances between 1979 and 1982 occurred in Madison County, with Kane County experiencing an exceedance in 1980.

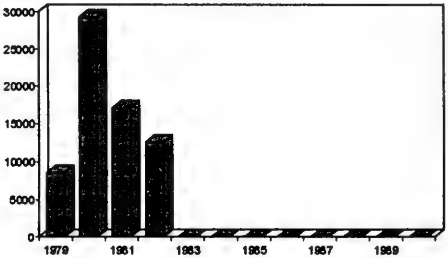

Figure 4. Estimated number of people exposed to significant levels of ambient lead.

OZONE

Ozone, a photochemical oxidant, results from a complex series of atmospheric reactions initiated by sunlight. In this process, ultraviolet (UV) light energy is absorbed by nitrogen dioxide, which then dissociates into nitric oxide and an oxygen atom. The oxygen atom, for the most part, reacts with atmospheric molecular oxygen (O_2) to form ozone (O_3). The nitric oxide reacts with ozone to re-form nitrogen dioxide, completing the cycle. The process, which has been simplified, is illustrated as follows:

$$NO_2 \xrightarrow{(UV)} NO + O$$
$$O + O_2 \longrightarrow O_3$$
$$O_3 + NO \longrightarrow NO_2 + O_2$$

The reaction cycle above defines an equilibrium concentration. A build-up of ozone above the equilibrium results when nitrogen oxide reacts with non-methane hydrocarbons (IEPA, May 1992).

Ozone can also be formed naturally in the atmosphere by electrical discharge, and in the stratosphere by solar radiation. Although these processes will not produce significant urban concentrations of the pollutant, there is some belief that incursion of ozone from the stratosphere can contribute significantly to elevated ground level concentrations under certain meteorological conditions (IEPA, May, 1992).

Generally the principal sources of ozone pollution in the air environment are transportation (40%), industrial processes (38%), miscellaneous sources (13%), fuel combustion (6%), and solid waste (3%) (IEPA, Nov. 1990).

Health Effects

Ozone is a pulmonary irritant, affecting the respiratory mucous membranes, other lung tissues and respiratory functions (IEPA, May. 1992, Lippmann, 1992, Klaassen, et al., 1986). Clinical and epidemiological studies have demonstrated that ozone impairs the normal mechanical function of the lung, causing alterations in respiration, the most characteristic of which are shallow, rapid breathing and a decrease in pulmonary compliance. Exposure to ozone results in clinical symptoms such as chest tightness, coughing, and wheezing. Alterations in airway resistance can occur, especially to those with respiratory diseases (asthma, bronchitis, emphysema). These effects may occur in sensitive individuals, as well as in healthy exercising persons, at short-term ozone concentrations between 0.15 and 0.25 ppm. Ozone exposure increases the sensitivity of the lung to bronchial constrictive agents such as histamine, acetyl choline and allergens, as well as increasing the individual's susceptibility to bacterial infection. Simultaneous exposure to ozone and SO_2 can produce larger changes in pulmonary function than exposure to either pollutant alone.

Historical Levels

Although the CAMP program began monitoring for oxidants in Chicago in the 1960's, it did not monitor for ozone on a broad scale until 1974, when it recorded hourly average values ranging from 0.02 to 0.16 ppm in July and 0.02 to 0.14 ppm in August (Quone and Wadden, 1975). The duration and intensity of the sun during the summer months stimulate considerable photochemical activity and ozone concentrations exceeded the ambient air quality standard frequently in 1974. In Chicago, the daily peak-hour ozone concentration equaled or exceeded 0.1 ppm (200 g/m^3) at one or more measuring stations on fifteen days in July and nine days in August (Quone and Wadden, 1975).

Exposure Assessment

Ozone exposure is illustrated in Figure 5. It should be noted that although any measurement above the current standard of 235 μg/m^3 (0.12 ppm) was used for this assessment, "for a site to attain the ozone standard, the three year average of expected exceedances must be less than one" (IEPA, 1991). Over the thirteen years, at least one year of ozone data was collected in twenty-eight different counties. In other words, all sites were not in operation the entire time period.

Since 1978, overall exposure has declined although there have been significant spikes, due to weather conditions, in 1983, 1987 and 1988. In 1978, exceedances occurred in 11 counties: Williamson, St. Clair, Madison, Sangamon, Peoria, Rock Island, Lake, Cook, Du Page, Will and Kankakee. In 1984, exceedances occurred in seven counties: Monroe, St. Clair, Madison, Du Page, Lake, Cook and Sangamon. Incidents were up again in 1987 and 1988, with more people exposed in 1987 and more incidents and higher measurements in 1988. In 1990, only Jersey County, downwind of the Metro East area, exceeded the standard. Weather conditions often cause ozone exceedances to occur downwind from a source.

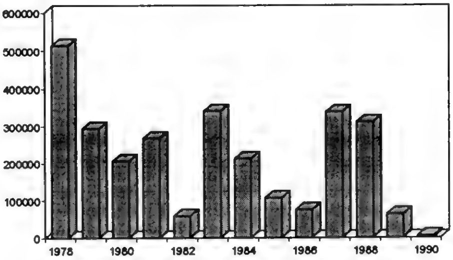

Figure 5. Estimated number of people exposed to significant levels of ambient ozone.

CARBON MONOXIDE

Carbon monoxide (CO), a colorless, odorless gas, is insidious in the onset of its effects; unlike the other major gaseous pollutants, it has no warning properties such as odor. With increasing concentrations, acute signs and symptoms of injury are headache, dizziness, lassitude, flickering before the eye, ringing in the ears, nausea, vomiting, palpitations, pressure on the chest, difficulty in breathing, apathy, muscular weakness, collapse, unconsciousness, and death (Stern, 1968). Carbon monoxide (CO) is emitted from virtually all sources of incomplete combustion, including internal combustion engines (automobiles, trucks, small gasoline engines); fires, both natural and man-made; improperly adjusted gas and oil appliances (space heaters, water heaters, stoves, and ovens); and tobacco smoking. In general the major source of CO is motor vehicles (IEPA, May 1992).

Health Effects

The toxic effects of high concentrations of CO on the body are well known. Carbon monoxide is absorbed by the lungs and reacts with hemoglobin (the oxygen carrying molecule in the blood) to form carboxyhemoglobin (COHb). This reaction reduces the oxygen carrying capacity of blood because the affinity of hemoglobin for CO is more than 200 times greater than that for oxygen. The higher the percentage of hemoglobin bound up in the form of COHb, the more serious is the health effect. The level of COHb in the blood is directly related to the CO concentration of the inhaled air (IEPA, May, 1992).

Evidence exists indicating a possible relationship between CO and heart attacks, cardiovascular disease and fetal development. Evidence also exists indicating a correlation between CO and aggravation of anemia, blood disorders, chronic lung diseases and neurological behavioral effects. Individuals with reduced blood hemoglobin concentrations, or with abnormal hemoglobin, will have reduced O_2 carrying capacity in the blood. (Berk et al., 1974; Solanki et al., 1988). Chronic lung diseases such as chronic bronchitis, emphysema and mixtures of both are characterized by impairment of the lung's ability to transfer O_2 to the bloodstream because diseased regions of the lungs are poorly ventilated, and blood circulating through these regions will therefore receive less O_2 (West 1987). Reduction of blood O_2 delivery capacity from the formation of COHb could exacerbate symptoms and further reduce exercise tolerance in these individuals. Decreases in alertness, visual perception, manual dexterity, and performance of complex sensory motor tasks are also correlated with elevated levels of CO (Lippmann, 1992).

Historical Levels

The annual averages from the CAMP sites in Chicago were as follows: 12.0 ppm (1964), 17.1 ppm (1965), 12.5 ppm (1966), not available (1967) and 6.2 ppm (1968). The daily hourly average of CO concentration in the Chicago region ranged from 6.4 ppm to 13.6 ppm in 1964 (USDHEW, 1969). During late August through early November 1973, using various instruments at different sites, the average carbon monoxide concentrations measured in Chicago ranged from 4 ppm to 7 ppm (Quone et al. 1974).

Exposure Assessment

Figure 6 presents exposure estimates based on the eight-hour standard of 9 ppm. The exposed population varied significantly between 1978 and 1984, peaking in 1983 when the standard was exceeded at several sites in Cook County and one site in Winnebago County. Between 1985 and 1986, and 1988 and 1990, the eight-hour standard was not violated at any of the monitoring stations. During the entire thirteen years, there was no exceedance of the one-hour standard of 35 ppm.

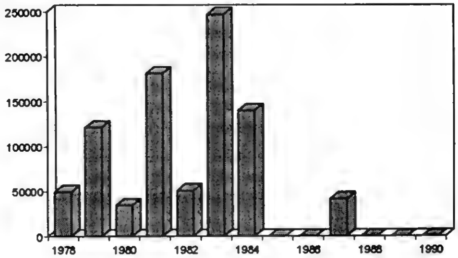

Figure 6. Estimated number of people exposed to significant levels of ambient CO.

NITROGEN DIOXIDE

Nitrogen gas (N_2) is an abundant and inert gas which makes up almost 80% of the earth's atmosphere. In this form it is harmless to humans and essential to plant metabolism. Due to its abundance in the air, it is a frequent reactant in many combustion processes. When combustion temperatures are extremely high, as in the burning of fossil fuels in most engines, atmospheric nitrogen (N_2) may combine with molecular oxygen (O_2) to form various oxides of nitrogen

(NO_x). They include gases and vapors such as nitric oxide (NO), nitrogen dioxide ((NO_2), nitrous oxide (N_2O), nitric acid (HNO_3); and possibly nitrogen trioxide (NO_3), dinitrogen trioxide (N_2O_3), nitrogen tetroxide (N_2O_4), dinitrogen pentoxide (N_2O_5) and particulates as nitrate (NO_3^-) salts. Nitric oxide (NO) and nitrogen dioxide (NO_2) are the most important of the NO_x in terms of air pollution and potential adverse health effects and are quite chemically reactive. Nitric oxide (NO) is a colorless and odorless gas. It is the primary form of NO_x resulting from the combustion process. The most important aspect of the relationship of NO_x with air pollution is the generation of ozone. The rates of formation and the steady-state concentrations of ozone are a function of light intensity, the concentrations of hydrocarbons and nitrogen oxides (the HC-NO_x ratio), and temperature (IEPA, May 1992).

Health Effects

Generally, there is a lack of strong evidence to associate health effects with most nitrogen oxide compounds. Specifically, the data base for health effects of nitric oxide (NO) is not extensive except for its interaction with blood (Lippmann, 1992). The major target for inhaled NO_2 is the respiratory tract where it can cause an increase in airway resistance, respiratory rate, and sensitivity to bronchial constriction, in addition to a decrease in lung compliance and an enhanced susceptibility to respiratory infections. NO_2 is a deep lung irritant capable of producing pulmonary edema and structural alterations in the respiratory tract if inhaled in sufficient concentrations. When NO_2 is inhaled with other pollutants, the effects are additive (IEPA, May 1992; Lippmann, 1992).

Historical Levels

Historical data was collected at a few sites for both nitric oxide and nitrogen dioxide and reported in hourly, daily or monthly averages or maximums. The annual arithmetic averages for nitric oxide were: in 1964, 0.10 ppm; in 1965, 0.096 ppm; in 1966, 0.101 ppm; and, in 1967 and 1968, 0.072 ppm. The annual arithmetic averages for nitrogen dioxide were: 1964, 0.046 ppm; 1965, 0.043ppm; 1966, 0.057ppm; 1967, 0.050 ppm; and 1968, 0.048 ppm (USDHEW, 1969).

Exposure Assessment

According to Figure 7 the number of people exposed to significant concentrations of NO_2 more than doubled between 1978 and 1979, then dropped to 10% of the 1979 figure by 1980. Since 1981, statewide air quality monitors have not recorded any NO_2 measurement above the standard.

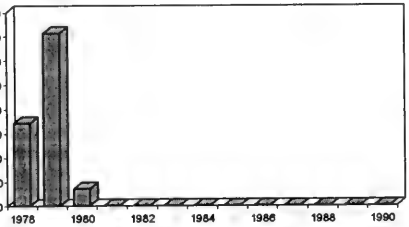

Figure 7. Estimated number of people exposed to significant levels of ambient NO_2.

PARTICULATES

All air pollution is not in the gaseous form; much of it is in the form of small solid particles called particulates. Because particulates entering the atmosphere differ in size and chemical composition, attempting to measure these variations over time is complex. Sources of particulates are fossil fuel combustion (ash and soot), industrial processes (metals, fibers, etc.), wind and mechanical erosion of local soil (fugitive dust), and complex chain reactions between sunlight and gaseous pollutant(s) (photochemically produced particles). According to IEPA, industrial processes account for about 38% of emissions, fuel combustion, 25%, transportation, 20%, solid waste, 4% and miscellaneous sources, 13% (IEPA, November 1990).

Particulate standards are based on size. Fugitive dust and industrial products are typically larger particles, greater than 1 micrometer. Particles which cause the most health and visibility difficulties measure less than 1.0 micrometer, such as combustion and photochemical particles, and are the most difficult to reduce by industrial removal techniques. They are removed from the air most often by rainfall.

Health Effects

Particulate pollutants enter the human body through the respiratory system, and this is where the most immediate effects occur. The size of the particle determines its depth of penetration into the respiratory system. Particles over 5 micrometers are generally deposited in the nose and throat. Those that do penetrate deeper into the respiratory system to the air ducts (bronchi) are often removed by ciliary action. Particles ranging in size from 0.5-5.0 micrometers can be deposited in the bronchi, with few reaching the air sacs (alveoli). Particles are not removed from the alveoli as rapidly or completely as they are from the larger passages. Those that are retained in the alveoli are absorbed into the blood stream. Particulates have been associated with increased respiratory diseases (asthma, bronchitis, emphysema), cardiopulmonary disease and cancer.

Historical Levels

Particulate matter is typically referred to as total suspended particulates (TSP). The TSP standard was replaced by the Particulate Matter 10 micrometers (PM_{10}) standard in 1987 because of the higher risk posed by the smaller particles. The historical data and exposure assessment looked only at TSP measurements, not PM_{10}.

Table 2 presents TSP measurements collected by a high volume air sampler from various sites in and around the Chicago and East St. Louis areas from 1966 to 1970. The annual average for the Chicago area remained fairly consistent, declining from an annual average of 113 $\mu g/m^3$ to 100 $\mu g/m^3$. The East St. Louis average also declined, from 153 $\mu g/m^3$ to 120 $\mu g/m^3$.

Table 2. Suspended particulates ($\mu g/m^3$) — Chicago and East St. Louis[a]
(Annual Geometric Mean)

Years	1966	1967	1968	1969	1970
Chicago Area					
No. of Sites	16	36	42	44	45
Average	113	112	108	110	100
Maximum	224	202	236	296	235
Minimum	60	60	44	48	55
St. Louis Area					
No. of Sites	6	10	6	11	11
Average	153	149	152	138	120
Maximum	199	202	216	281	207
Minimum	110	115	114	87	11

a) IEPA, 1971.

Exposure Assessment

Between 1978 and 1990, TSP was monitored in thirty-six counties, although monitoring was not consistent over the thirteen years in all counties. Figure 8 shows the population exposed to quantities of particulates greater than the twenty-four hour primary TSP standard. The peak year was 1983 when approximately 1.25 million people were exposed in the counties of Lake, McHenry, Winnebago, DeKalb, Kane, DuPage, Cook, Will, Kankakee, Grundy, LaSalle, Peoria, Tazewell, McClean, Sangamon, Macon, Champaign, and Madison. The next highest exposure was in 1985 with .9 million exposed. After 1985 the numbers significantly declined, but it should be noted that when PM_{10} superseded the TSP regulations, TSP monitoring declined. This is discussed in more detail in Volume 1, Air Resources.

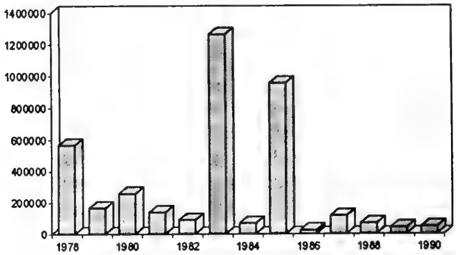

Figure 8. Estimated number of people exposed to significant levels of ambient TSP.

CONCLUSION

Long term air quality monitoring has been conducted for regulatory purposes, not for assessing statewide trends in exposure. However, given the assumptions made in this analysis, the improvements made in ambient air relative to criteria air pollutants indicate that exposure has declined considerably.

The NO_2 standard has not been exceeded since 1980, the lead standard since 1982, and the SO_2 standard since 1988. CO has been exceeded only once since 1985. Although TSP and ozone had exceedances every year during this time period, exposure levels declined significantly. In 1990, the number of people exposed to ozone dropped to 2% of the 1987 level, one of the peak years, and TSP exposure was down to 4% of the 1983 level, the maximum for the period.

If additional time and resources had been available, a more accurate buffer could have been developed. Additionally, if data for other compounds had been available, additional estimates could have been developed. Future efforts will attempt to incorporate recent monitoring efforts or modeled estimates for a larger array of compounds. Combining such efforts with the Pollutant Standards Index[3] or other measurements could improve the accuracy of air quality trends information.

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[3] The Pollution Standards Index (PSI) is used in Illinois to inform the general public about air pollution levels. The index combines daily ambient concentrations of criteria pollutants with the levels of risk posed by those pollutants to describe daily air quality as being good, moderate, unhealthful, very unhealthful, or hazardous. Based on the PSI, IEPA has reported that daily air quality in Illinois has never been classified as 'hazardous', has rarely been designated as being 'very unhealthful' and that even 'unhealthful' is not commonly used. Long-term data was not readily available to present trends using this index.

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HUMAN EXPOSURE TO WATER POLLUTION

Regulations to protect drinking water in the United States date back to the late 1800's with the Interstate Quarantine Act of 1893. The first federal drinking water standards were issued in 1914 and were administered by the US Public Health Service (USPHS). Because the commission which set standards could not agree on specifics for chemical and physical requirements, the 1914 standards were limited to a bacteriological standard. Revised several times, the standards covered 28 constituents by 1962.

As part of its effort to revise the 1962 standards, the USPHS conducted a comprehensive survey of water supplies, the Community Water Supply Study, in the late 1960's. "A major finding of this study was that while a majority of the population studied (59%) were served water that met the standards, 25 percent of the systems delivered water that exceeded at least one of the recommended limits and 16 percent exceeded one or more of the mandatory limits." (USPHS, 1970) Several follow-up studies came to similar conclusions and helped lead to the passage of the 1974 Safe Drinking Water Act (SDWA), with primary authority vested in the recently created U.S. Environmental Protection Agency (USEPA). The Safe Drinking Water Act requires USEPA to set numerical standards and public water supplies to monitor for specific substances and to incorporate the best available technology to meet the federal requirements. The SDWA was amended several times, most significantly in 1986 with amendments to speed up the rate at which standards are established (see Figure 1, developed from Frederick W. Pontius, "SDWA: A Look Back", Journal of the American Water Works Association, February 1993).

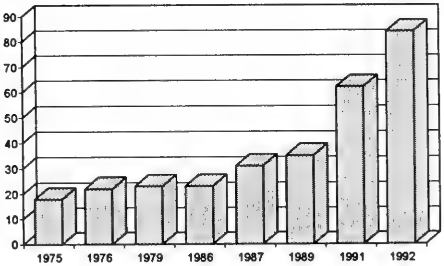

Figure 1. The number of federal drinking water regulations promulgated in the time period 1975 - 1992.

In Illinois, the Illinois Environmental Protection Agency (IEPA) obtained primacy for the Safe Drinking Water Act in the late 1970's and regulates the public water systems (PWS) upon which this assessment is based. According to the IEPA, there are 121 surface water PWS, 1347 ground water PWS, and seven PWS using both surface and groundwater. The populations serviced by the ground and surface water systems are roughly equal (IEPA 1992).

EXPOSURE ASSESSMENT

An approach similar to the air exposure assessment was planned for the drinking water exposure assessment, whereby a 'risk' or 'no risk' assumption would be made depending on whether drinking water measurements exceeded the appropriate health standard. Illinois drinking water standards, Federal maximum contaminant levels (MCLs) and general health criteria were obtained and developed into a database which would identify those PWS whose monitoring results exceeded a standard. The PWS data were requested from IEPA's computer database (Sample Automation/Facility Evaluation); data was first obtained for organics, radiological compounds, and turbidity.

A preliminary analysis of the organics data was conducted to determine facilities with reported exceedances. The findings did not compare with published results and time and resources did not allow for further analysis to develop comparable exposure trends. For illustrative purposes, Figure 2 presents a regulatory indicator for groundwater VOC contamination that was presented in the IEPA *1990-1991 Water Quality Report.*

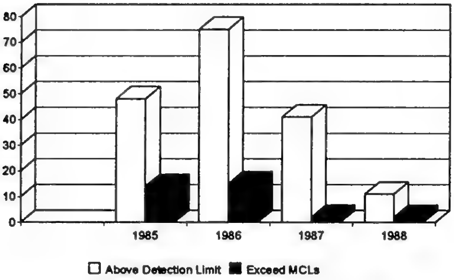

Figure 2. IEPA's Groundwater Regulatory Indicators for VOCs: the number of wells exceeding MCLs or above detection limit.

Because of the difficulties encountered, a surrogate for actual monitoring data was used — the public water supply Restricted Status List, submitted quarterly by IEPA and published by the Illinois Pollution Control Board in its *Environmental Register.* 'Restricted Status' "was developed to give additional notification to officials of public water supplies which are in violation of the Illinois Pollution Control Board Rules and Regulations, Chapter 6: Public Water Supplies, or the Illinois Environmental Protection Act. The Restricted Status List will include all Public Water Supplies for which the Agency has information indicating a violation of any of the following requirements: Finished water quality requirements of Rule 304 of Chapter 6; maintenance of adequate pressure on all parts of the distribution system under all conditions of demand; meeting raw water quantity requirements of Rule 308 of Chapter 6; or maintenance of treatment facilities capable of providing water 'assuredly adequate in quantity' as required by Section 18 of the Illinois Environmental Protection Act." (Pollution Control Board, Environmental Register, vol. 245, Oct. 6, 1981)

The Restricted Status List is an enforcement tool that "(t)he Illinois Environmental Protection Act provides that permits for water main extensions shall not be granted if the public water supply does not meet state standards for water quality. ...... The statute also provided that in cases where its application would cause unreasonable and arbitrary hardship, the IPCB could grant variances." (Blazer and Zeni, 1985)

Restricted status only indirectly relates to exposure; no direct correlation to human health is assumed. The Restricted Status List was used because it was the only consistent information for drinking water quality that was available to the Department for this study. It should be noted that only those facilities restricted because of SDWA violations[1] were included in the analysis[2].

The earliest *Environmental Register* to contain the list was 1981. The quarterly reports were summarized into an annual total whereby any facility listed for at least one quarter of the year was included in the annual summary. 'Facility' in this context refers to a unique identification number assigned by the IEPA.

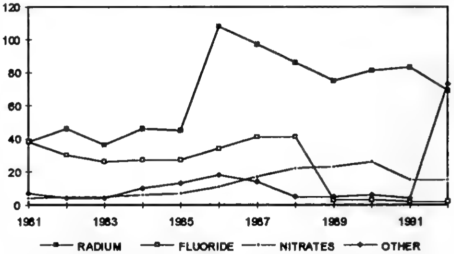

Figure 3. The number of PWS facilities on restricted status.

FINDINGS

Trends were developed for restricted status due to radium, fluoride, nitrates, and 'other' — total trihalomethanes (TTHM), organics, barium and miscellaneous compounds. (Figure 3) While radium and fluoride are naturally-occurring substances in Illinois groundwater, nitrates typically occur in drinking water as the result of fertilizer application, feed-lot runoff, or leaking septic tanks. Trihalomethanes are largely the result of chlorination, part of the water treatment process.

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[1] It should also be noted that facilities which have a one-time exceedance are not always included on restricted status.

[2] A large number of facilities are restricted because of system operation concerns, such as inadequate pressure.

During 1986, eleven percent of all public water supply systems were on restricted status due to contaminants, the highest percentage of the twelve-year period. The number of facilities restricted for radium increased 64% between 1981 and 1986, then declined considerably, probably due to communities switching to shallow wells or Lake Michigan as their source of water supply. The number of facilities restricted due to fluoride decreased significantly after 1988, from 41 facilities to two by 1992. Facilities listed for nitrates increased 84% between 1981 and 1990, but the number has since declined, from 26 facilities in 1990 to 15 facilities in 1992.

The 'other' category owes its dramatic increase in 1992 to a significant number of facilities being listed for total trihalomethanes. It is assumed that this increase was due to a 1991 change in the TTHM regulations which expanded the universe of facilities subject to the TTHM standard.

In summary, the Restricted Status List cannot be solely relied on to assess human exposure to drinking water contaminants. Given the importance of drinking water and the significant amount of resources dedicated to its protection, a metric needs to be developed that will better communicate the overall quality and trends in drinking water.

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Trends in manufacturing, transportation, urban dynamics, and electricity generation were examined as were trends in greenhouse gases, indoor radon exposure, accidental releases, wastewater discharges, and human exposure to air and water pollution. Overall, economic output for the sectors studied generally increased between 1970 and 1990. Transportation activity and electricity generation also increased. Over the same time period, however, emissions of traditionally regulated pollutants decreased in both air and water. Accompanying the decrease in water and air emissions of these pollutants is a decrease in human exposure to them.

From the manufacturing sector, statewide emissions of criteria pollutants decreased. Emissions of particulates are down 87%, sulfur oxides 67%, nitrogen oxide 69%, hydrocarbons 45% and carbon monoxide 59%. Transportation emissions dropped significantly, with a 20% decrease in NOx, and a 45% decrease in VOCs and CO while highway miles traveled grew by more than 40%. Fossil fuel emissions from electricity generation declined substantially, SO2 by 40%, NOx 19%, particulates 81%, and CO 36%. However, the level of radioactivity from low level nuclear waste, based on a five-year average, increased from 426 curies in 1974 to 41,000 curies in 1991.

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